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Re-inventing Harmony in Electroacoustic Music:
A commentary on my Recent Music

Paulina Sundin

A portfolio of original compositions and commentary submitted to
the University of Huddersfield in partial fulfilment of the
requirements for the Doctor of Philosophy

October 2010

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Abstract

Re-inventing Harmony in Electroacoustic Music reflects on research regarding structuring pitch-based material in my music written between 1999 and 2010. The selected works illustrates the process leading up to my research based on psychoacoustic consonance and dissonance and my strategies to create a new kind of harmony – a harmony based on concrete sounds with inharmonic spectra.

The discussion will refer to pieces by composers who have worked with harmony based on the analysis of sound spectra; instrumental and mixed works by spectralist composers such as Grisey, Murail and Saariaho and electroacoustic works by Harvey and others.

I will address the importance of research in the psychoacoustic field, in particular, research by William A. Sethares regarding inharmonic spectra and scales and how it has affected my works.

Paulina Sundin – list of works presented for PhD

<u>Title</u>	<u>Duration</u>	<u>Year</u>
Ti Chor - saxophone quartet (s, a, t, bar) and fixed media in stereo	8'50	1997/1999
Reflections - fixed media in stereo, 8 and 12-channels Collaborative work with composer Jens Hedman	9'00	1995/1999
Mayfly - fixed media in stereo	2'20	1999
Clandestine Parts - fixed media in stereo and 8-channels	8'09	2000
Med lekande kval - fixed media in stereo and 5-channels	3'10	2001
Within a Dream - fixed media in stereo	7'50	2002
Utresa - fixed media in stereo and 5-channels	7'00	2003
Joker - fixed media in stereo and 5-channels	13'00	2003
Klangstenen i Håga - fixed media in stereo and 5-channels	7'40	2006
Taal Bundu - saxophone quartet (s, a, t, bar) and fixed media in stereo	9'15	2009
Ytspänning - string orchestra (9 vn, 3 va, 2 vc, 1 cb) and saxophone quartet (s, a, t, bar)	10'00	2010
Echo in Silence - percussion, trombone and fixed media in stereo	8'00	2010
<hr/>		
Total duration:	1 hour 34 minutes	

Chapter 1: Context

1.1: Introduction

The following commentary relates to my research regarding structuring sound material in my works included in the portfolio written between 1999 and 2010. The selected works illustrates my work with harmony in general and my research based on psychoacoustic consonance and dissonance and my strategies to create a new kind of harmony – a harmony based on concrete sounds with inharmonic spectra.

The modernistic concepts presented by the theorist and composer Jan W. Morthenson in his compendium “*Komponerandets grunder*”¹ (*The Foundations in Composition*) in 1986 had an affect on my compositional strategies for many years. I was influenced by the concept that every note/pitch should be carefully weighed against the next and the previous one, and that all musical parameters should be varied. Using tonal melodies and harmony based on chords such as minor and major triads were strictly forbidden as well as repeating material. An opening such as Gérard Grisey’s *Partiels* (1975) where the first four bars would be repeated several times or the third movement of György Ligeti’s *String Quartet No. 2* (1968) where the same notes are repeated would have been a taboo in my early aesthetics influenced by Morthenson’s modernistic approach as no repetition of material was allowed.

To compose for the electroacoustic medium seemed to me a way out of such restrictive modernist aesthetics as I could work with parameters others than the ones related to the 12 notes in an equally tempered scale, parameters such as infinite variations of timbre, spatial placement, sound transformations etc. However, not even in electroacoustic music could I avoid working with pitch and I found it hard to abandon my classical music background in counterpoint and classical composition techniques. The use of melodic thinking in music was, and is, important to me, but in the 1990s when I was influenced by modernistic tendencies I needed to find a way of working with pitch and melodies in a new way. The modernistic aesthetics made me search for new ways to construct harmony in order to avoid traditional harmonic relations, research that began with the mixed piece *Ti Chor* (1999).

¹ Morthenson, J. W., ‘Komponerandets grunder’, Rikskonserter/Regionmusiken, Stockholm (1986).

The concept of using tonal material as in *Within a Dream* (2002) and *Taal Bundu* (2009) was a way of completely liberating myself from the modernistic inheritance formed by my years at the Royal College of Music in Stockholm (1993-1999) in particular. The pieces between 1999 and 2002 describe different compositional techniques, ways to structure sound material and work with harmony before I began my research into the field of psychoacoustics. All other pieces composed between 2003-2010 included in my portfolio are a combination of my desire to work with scales and melodies and the search for a new harmony based on non-traditional western harmony.

1.2: Methods of structuring material used

A single sound conceals a veritable universe. A sound is the seed of a chord, a motif, a form and finally a complete composition.²

Ever since I began composing music I have been searching for a way of structuring the musical material within my works. Usually, I would be inspired by a specific sound upon which I would base an idea for a piece, such as using only one original sound source and deriving all material from this sound (as in my first fixed media piece *Kontakt* from 1992 where all sound material was derived from the sound of a metal refrigerator shelf). Already then, I was interested in using a single sound source in order to determine the material of a piece, an idea that has been modified since but is still present in my works such as *Ti Chor*, *Utresa*, *Joker*, *The Ringing Stone of Håga*, *Ytspänning* and *Echo in Silence* included in this portfolio.

With the works in this portfolio I have been exploring different ideas of structuring material based on the following concepts:

1. Harmony
2. Spectral content
3. Programmatic content
4. Visual image
5. External musical factors

Some of these concepts interact together as one, depending on how they were used. For example: using harmony as a way of structuring material was in *Ti Chor*, *Utresa*, *Joker*, *The*

² Nieminen, R., quotation from programme note concerning Saariaho, Kaija, *IO*, (Finlandia, 1989), FACD 374.

Ringing Stone of Håga, *Ytspänning* and *Echo in Silence* based on spectral principles whereas in *Med lekande kval* and *Within a Dream* other parameters were used.

The main focus for the majority of the works included is an extended concept of harmony as an underlying structure, using analysed spectra from recorded concrete sounds to explore and develop new harmonic relationships in a work; in essence, to re-invent harmony in my electroacoustic music. I have also used these techniques in a number of instrumental pieces to illustrate this research.

1.3: Searching for a new harmony

To seek out new tonalities, new timbres...
To boldly listen to what no one has heard before.³

In traditional western music the 12-tone equal temperament tuning system has had a strong hold on music produced during the last 300 years. The tempered tuning system is a mathematical construction, a compromise in order to be able to modulate to all keys in the traditional western harmony – achieved by dividing an octave in 12 equal parts.

Coming from a traditional musical background playing classical music on the violin and piano I have of course been affected by this way of structuring sound material, practicing the equal temperament 12-tone scale all my life. This influence may be heard to a certain degree in *Reflections*, *Mayfly* and *Clandestine Parts* and to a greater degree in *Med lekande kval*, *Within a Dream* and *Taal Bundu* included in this portfolio.

The opening quotation from William A. Sethares suggests similarities with my own aesthetic that has emerged ever since I composed *Ti Chor* in 1999. Something that interested and puzzled me was whether or not there was a way to create a harmonic framework not based on the traditional western harmony and idiosyncratic to electroacoustic music. *Ti Chor* was my first attempt to explore this path, using spectral analysis of saxophone multiphonics and creating non-tempered scales based on the strongest (in amplitude) partials. The idea was to generate sounds for the fixed media part with the same spectrum as the original multiphonics, sounds that could be transposed according to the scale steps with the spectrum content intact.

³ Sethares, W. A., *Tuning, Timbre, Spectrum, Scale*, Second Edition, Springer-Verlag London Limited, (2005), Prelude V.

In 1996 when I began composing *Ti Chor* I lived in Stockholm, working at EMS and at the Royal College of Music. I was, at the time, not aware of the spectralist composers and their method of structuring musical material by using analysed spectra. I was not aware of and did not have access to the computer programs that Jonathan Harvey used in *Mortuos Plango, Vivos Voco* (1980)⁴ or that Kaija Saariaho used in her fixed media piece *Vers le Blanc* (1982)⁵.

My source of inspiration was listening to Denis Smalley's mixed pieces *Piano Nets* (1990-1991) and *Clarinet Threads* (1985) as I thought these pieces were good examples of combining instruments with fixed media. In *Ti Chor* I wanted to integrate closely the spectral content of the fixed media part with the instrumental part in order to create a perceptual ambiguity during performance. In *Piano Nets* for piano and fixed media, Smalley used a variety of chord-flavours and sonorities in the piano part such as chords of thirds, fourths and whole-tone chords with the piano playing in a chordal style. This according to Smalley enabled,

... a concentrated exploration of subtle blendings of piano and electro-acoustic sounds. The relations between piano and electroacoustic sounds vary – they can be mutually decorating or supporting; they can act in a cause and effect manner; they collaborate in attacking events and resonance colorings; the electroacoustic sounds can sound as if emanating from inside the piano's sound, or conversely [...].⁶

In *Clarinet Threads* a lot of extended playing techniques were used in the clarinet part including key noises, air sounds, less definite pitches, very high notes produced by biting the reed and multiphonics. According to Smalley, the clarinet,

... is threaded through the electroacoustic fabric, sometimes merged with it, sometimes surfacing in a more soloistic role.⁷

Inspired by these two pieces by Smalley, I used extended playing techniques in *Ti Chor* in order to merge the instrumental part with the fixed media part. My goal was that the sounds of

⁴ IRCAM based program such as MUSIC V described in: Harvey, J., 'Mortuos Plango, Vivos Voco: A Realization at IRCAM'. *Computer Music Journal*, Vol. 5, No. 4, (Winter 1981), pp. 22-24.

⁵ IRCAM based program such as CHANT described in: Pousset, D., 'The works of Kaija Saariaho, Philippe Hurel and Marc-André Dalbavie', *Contemporary Music Review*, Vol. 19, Part 3, (2000), p. 70.

⁶ Quotation from programme note: Smalley, D., *Impact intérieurs* (empreintes DIGITALes, 1992), IMED-9209-CD, p. 16.

⁷ Quotation from programme note: Smalley, D., *Impact intérieurs* (empreintes DIGITALes, 1992), IMED-9209-CD, pp. 18-19.

the instruments and the fixed media part would be completely integrated to be equally important. The idea behind using extended playing techniques such as multiphonics and air sounds was that these sounds could be used without reference to traditional harmony. In *Ti Chor* I used chords based on analysed inharmonic spectra in my search for new harmony as will be explained in detail in chapter 2.1.

1.4: The influence of musique concrète works

I began working at EMS in 1991 and was at the time very much involved with the Swedish electroacoustic community. EMS was the hub where composers would meet and exchange ideas. The Stockholm Electroacoustic Music Festival and the Skinnskatteberg Festival attracted international composers to Sweden and at the time a lot of Swedish composers had international success at the Bourges Synthèse Festival. During this time I was busy developing my own voice as a composer and the influence of other composers can be traced back to specific works composed at the time.

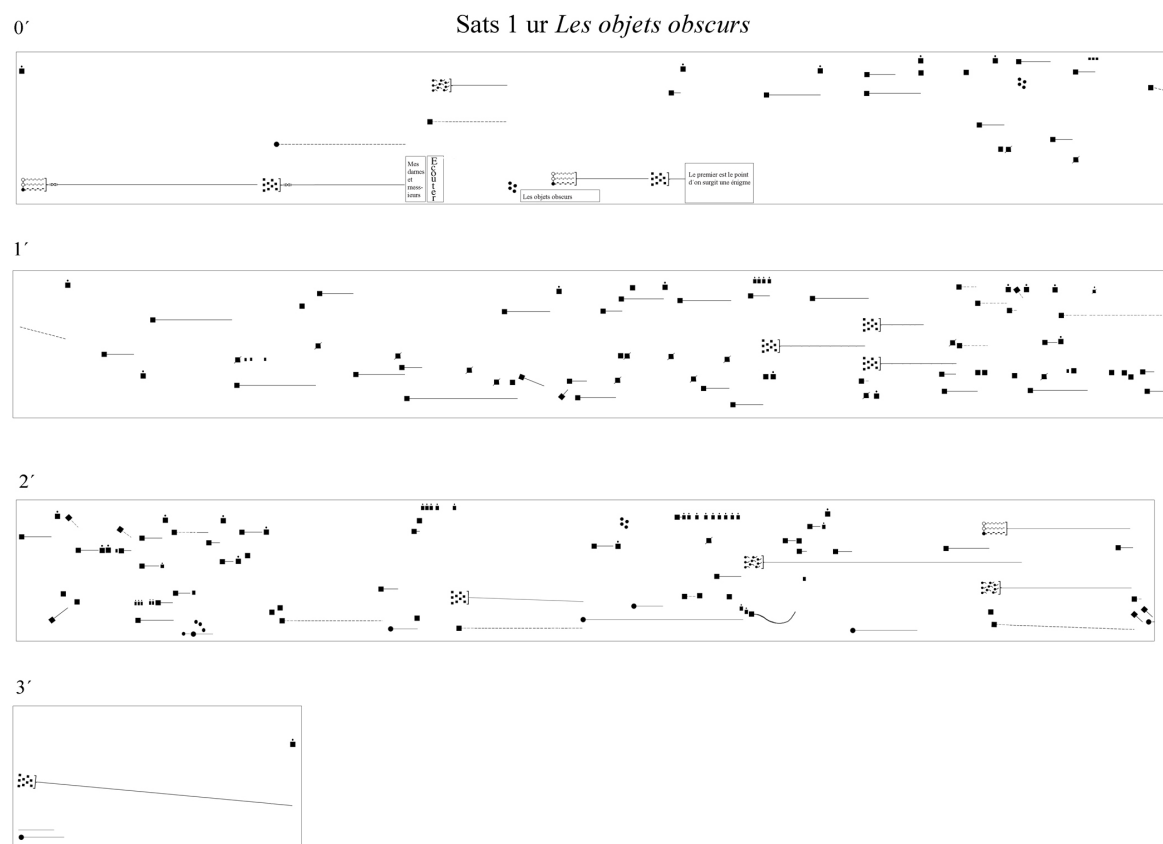
A piece that has influenced some of my later works is *Les Objets Obscurs* (1991) by Åke Parmerud. In the programme note Parmerud refers to the musique concrète tradition in how he created the piece in four movements. Parmerud writes that the

Concept as well as material and compositional methods lies within the basic framework of the classical “musique concrète”. [...] Each movement is based upon sounds and transformations of sounds produced by one single every day object (like a chair, a glass). One movement – one object.⁸

The idea of using one single sound object and deriving material from that sound throughout the whole piece was something that appealed to me early on in my work. When I heard *Les Objets Obscurs* for the first time I was intrigued by how Parmerud had derived the material from a concrete sound without much pitch content and yet each new processed sound seemed to have a deliberate pitch. The third movement, based on the sound of twenty-two stone marbles, was especially interesting, as I perceived an underlying harmony that I was not familiar with. In order to understand how the piece was structured in time I made a score for

⁸ Quotation from programme note: Parmerud, Å., *Invisible Music* (Phono Suecia, 1994), PSCD 72.

each movement based on Lasse Thoresen's symbols of Pierre Schaeffer's typology of sound objects⁹ (see Figure 1.1).



Notation: Paulina Sundin©1998

Figure 1.1: A transcription of *Les Objets Obscurs*, first movement.

When the score was completed, I could follow the events and layers throughout the piece more easily and it inspired me to work with short concrete sound objects with identifiable pitch. In *Med lekande kval* (2001) all sounds were given a specific pitch as will be discussed in Chapter 2.5. The gestures in the first movement in *Les Objets Obscurs* served as an inspiration when I composed the theme heard at 2'05 (Sound example 33) in the piece *The Ringing Stone of Håga* (2006). The choice of using chair sounds in *Med lekande kval* was partly a nod to the second movement of Parmerud's piece which uses a similar source sound and partly a tribute to Akos Rozmann's seminal work *Crypt with table and chairs* (1989-1990).

⁹ Thoresen, L., "Auditive Analysis of Musical Structures. A summary of analytical terms, graphical signs and definitions." *Proceedings from ICEM Conference on Electroacoustic Music Stockholm, Sweden, 25 –27 September 1985* (Editor: Bo Rydberg 1988), pp. 65-90.

Inspired by the harmony in *Les Objets Obscurs*, I wanted *Med lekande kval* to have an underlying harmonic structure that was not necessarily perceivable by the listener but used as a way to structure pitch within the piece. *Med lekande kval* is based on a song by the 18th century poet Carl-Michael Bellman. Parmerud had similarly used a pre-existing work as inspiration for his work *Alias* (1990). However, whereas Parmerud used the renaissance harmony of John Dowland and Gesualdo da Venozza in his piece *Alias*, I did not want the Bellman's harmonic structure (see page 81-82) to be audible in my work. *Med lekande kval* is not a post-modern electroacoustic work, freely using quotation of an older work and weaving into the fabric of a new one, as in Parmerud's. Rather my appropriation of the older work embeds the harmonic structure of the original into something entirely new – much like Birtwistle's use of renaissance isorhythmic techniques.

1.5: Using traditional western harmony with an imported musical structure

Incorporating musical material made by another composer is quite a common technique in most genres of music, even so in electro-acoustic music. The imported material might be used and treated in various ways and the ideas behind the use of imported music in electroacoustic music have been various – from transmitting political messages to purely aesthetical reasons. Using “borrowed” audio recordings and re-arranging them with cut-up techniques are today wide-spread compositional methods, used by John Oswald in his *Plunderphonics* and by acousmatic composers such as Jens Hedman in his piece *Mix-up* (2000). Previous to this, Karlheinz Stockhausen used music other than his own in his compositions. Stockhausen's *Telemusik* (1966) was based on numerous recordings of ethnic and world music and *Hymnen* (1966-1967) was based on the national anthems from all over the world. Another well-known example is *Novars* (1989) by Francis Dhomont, a piece dedicated to musique concrète and Pierre Schaeffer in which

The ‘classical’ ear will perhaps recognize fragments from Schaeffer's *Étude aux objets* (1959) and Guillaume de Machaut's *Messe de Nostre Dame* (1364). These quotations, along with a third sound element – a sort of homage to Pierre Henry and his infamous door – are the sole materials giving birth to multiple variations.¹⁰

¹⁰ Quotation from programme note: Dhomont, F., *Les dérives du signe*, (empreintes DIGITALes, 1991), IMED 9608.

According to Andrew Lewis in his analysis of *Novars*, Dhomont uses filter-swept chords derived from resonances taken from the first movement of Schaeffer's piece, and that these sounds form a running thread throughout the work as they are present for almost 60% of the total duration of the piece. The analysis also shows that the family of sounds based on "single, frozen chords taken from the *Messe*"¹¹ (*Messe de Nostre Dame* by Machaut) are present in almost 40% of the total duration of the piece. Together with the resonance sounds and sounds of "door creaks and slams" these three sound categories are most consistently present in *Novars*, and the other sound types present

have a more auxiliary function, serving to support, develop or accompany the first three.¹²

Another electroacoustic work composed the same year as Dhomont's *Novars* was *Jeu* (1989) by Robert Normandeau. The piece *Alias* by Åke Parmerud was composed only a year after *Jeu* and I will compare these two pieces in order to clarify two different approaches and how they relate to my own compositional techniques. The latter composition, *Alias*, seems constructed with the imported tonality in mind and with recognizable references to Dowland and Gesualdo embedded in the piece¹³. A perception of tonality is perceived throughout the whole piece, i.e. a conscious tonality is present in most sound material, not only in the imported musical material. In Normandeau's *Jeu*, only the actual sampled/imported music by Perotin (the piece *Organum Viderunt omnes*, probably written for the Christmas season of 1198)¹⁴ contains a perceivable harmony, the other sound material used within the piece is not pitched. The imported music by Perotin is used merely as sound material as no conscious tonality is perceivable in *Jeu*.

In Dhomont's *Un autre Printemps* (2000) - "A tribute to nature, spring, 'musique concrète' and to the famous Vivaldi Concerto"¹⁵ - an approach related to that of the Normandeau piece is detected. There are excerpts of Vivaldi's *Spring Concerto* from the *Four Seasons* (1723) and additional viola string sounds but apart from that obvious tonal material there is no attempt to embed it with other than "un-pitched" musique concrète material.

¹¹ Lewis, A., 'Francis Dhomont's *Novars*', *Journal of New Music Research*, Vol. 27, No. 1-2, (1998), pp. 67-83.

¹² Ibid 11, p. 70.

¹³ Bridgeman, E., 'Overall Analysis of "Alias" by Åke Parmerud', 2009, published on http://www.parmarud.com/MediaArtist/Alias_analys.html. Accessed 15 August 2010.

¹⁴ Quotation from CD leaflet: Munrow, D., *Music of the gothic era*, (Archiv production, 1976), AH 415 292-2, p. 10.

¹⁵ Excerpt from the program note of the piece *Un Autre Printemps* by Francis Dhomont at the ICMC in Gothenburg 2002.

Med lekande kval and *Within a Dream* resemble the approach that Parmerud took in *Alias* in the sense that they consist of pitched material other than that of the imported or sampled music.

In *Within a Dream* (2002) the imported material of the piece consisted of recordings of songs composed by Carin Bartosch-Edström with the original recordings clearly audible in the piece as in the previously mentioned works by Dhomont, Parmerud and Normandeau. If Dhomont in *Novars* used imported sounds as a way of structuring the harmonic content within his piece as well as a carrier of surface level material, then it resembles my approach in *Within a Dream*. However, in *Med lekande kval* the imported harmonic frame was used merely as a background scaffold underpinning the structure of the work and no sound material from the Bellman piece was used.

1.6: Spectrum based harmony in electroacoustic music

There is a connection between harmonic spectra and traditional western harmony. This connection has been thoroughly investigated, beginning with the ancient Greeks via Jean-Philippe Rameau, Paul Hindemith and, more recently, spectralists such as Gérard Grisey and Tristan Murail. My work however, has been focused on developing new logical harmonic relationships other than those based on traditional harmonic overtones. My research has involved the spectral analysis of already existing sound sources with inharmonic¹⁶ spectra, examining their partial content and then building scales and harmony derived from these spectra.

To synthesise sounds based on stretched or diminished spectra or other kinds of spectra has been developed significantly over the past forty or so years by a number of acoustic and electroacoustic composers. Building non-harmonic spectra with techniques like frequency modulation, amplitude modulation and ring modulation has been possible since the early days

¹⁶ Inharmonic should not be confused with the term “Inharmonicity” which is a measure of deviation of a partial from the closest ideal harmonic. As explained in [http://en.wikipedia.org/wiki/Harmonic_series_\(music\)](http://en.wikipedia.org/wiki/Harmonic_series_(music)): Typical pitched instruments are designed to have partials that are close to being harmonics, with very low inharmonicity; therefore, in music theory, and in instrument tuning, it is convenient to speak of the partials in those instruments' sounds as harmonics, even if they have some inharmonicity.

of electroacoustic music and experiments with finding hierarchical structural functions¹⁷ based on these techniques have already been explored to a certain degree¹⁸. But to explore a functional harmonic system based on non-synthesised inharmonic spectra, an analysed spectrum of a concrete sound is more unusual.

After researching the literature concerned with electroacoustic music I have not found many composers who are involved in creating compositions based on analysed concrete sounds with a harmony based on a *different* fundament than of the harmonic spectra. One example is however, Jonathan Harvey's *Mortuos Plango, Vivos Voco* (1980), a fixed media electroacoustic composition with harmony based on an inharmonic spectrum: the spectrum of the great tenor bell at Winchester Cathedral. The work is divided into eight sections, each with a different central pitch which functions as the “pivot” of the modulation, having their origin in eight pitches from the bell’s spectrum. The duration and all the melodic material are determined by the spectrum. Here is a piece where:

[...] every event, down to the smallest detail, can be deduced directly back to the bell spectrum and the eight pitches extracted from it.¹⁹

The influence of Harvey’s piece in my works may be heard in *Clandestine Parts* (2000) where I analysed the sound of a bell and then used the bell’s spectrum to determine the pitch content of other sounds as will be discussed in Chapter 2.4 (see page 71-77).

In *Le Partage des Eaux* (1995) and *Bois flotté* (1996), Tristan Murail has explored harmony based on the spectral analysis of non-harmonic sounds using synthesis in order to

find an orchestral sound that was both new, and yet somehow linked to the period of “grand orchestration” (the orchestra at the end of the 19th and beginning of the 20th century).

In *Le Partage des Eaux* (1995) Murail used material derived from the spectral analysis of waves, a breaking wave and its “backwash”. The breaking wave

¹⁷ See Dashow, J., ‘Spectra as Chords’, *Computer Music Journal*, Vol. 4, (1980), pp. 43-52.

¹⁸ Example of a new but closely related tonal system is the Bohlen-Pierce scale. It is tempered with 13 notes in an “octave” with the ratio 3:1. It is based on triads and it is possible to modulate to parallel keys. In order to work only sounds with odd partials are to be used (e.g. 1, 3, 5, 7...). See *Current directions in Computer Music Research*, Ed. Max V. Mathews and John R. Pierce, 1989.

¹⁹ Anderson, J., ‘A Provisional History of Spectral Music’, *Computer Music Review*, vol. 19, Part 2, (2000), p. 19.

is manipulated, transformed, expanded or compressed in many ways. It contains strangely coloured and strangely coherent harmonic-timbres. In slow motion, it becomes a sluggish somewhat obsessional melodic-harmonic element that while defining the piece, is often interrupted by other musical structures.²⁰

The sound based on the spectral analysis of the “backwash” was according to Murail used three times and contained

typically aquatic rhythms and amplitude changes - like sorts of sound splashes - and very scattered (quasi “chaotic”) pitches. The third time, the “backwash” is “tuned” over a large orchestral spectrum that stabilizes it harmonically, while at the same time endowing it with a distant and nostalgic quality.²¹

However, Murail uses spectral analysis and synthesised sounds in an instrumental context rather than idiosyncratic to the electroacoustic medium in his search for “a computer assisted orchestra”. The role of the synthesised sound in *Le Partage des Eaux*

is to complete the orchestration (simulating, for example, a quartertone harp or vibraphone), or to clarify, enrich or smooth the sonic textures. Rather than being perceived as such, they are totally integrated into the orchestration. I see this as the initial steps toward the concept of “a computer assisted orchestra”...²²

Many electroacoustic composers have been involved in finding ways of exploring harmony but usually based on abstract mathematical principles or on refinements of the traditional western harmony. Composers like John Chowning in his electroacoustic work *Stria*, Kaija Saariaho in *Vers le Blanc* or Jean-Claude Risset in *Songes* and *Inharmonique* work with harmonic consistency, to name but a few.

I feel a conscious need for harmony in electroacoustic music, especially so in my own music. I have tried to escape the pitch domain completely, focusing on rhythm, space, gestural events etc. but always ended up wanting to work with pitch again. So, if I cannot escape pitch, then I feel that I need to find a fruitful way of working with it.

1.7: Inharmonic spectrum based harmony in ‘spectral’ music

Harmony, through its relation to form, gave tonal music its strength; nowadays, it has too often been reduced to a simply decorative function. The mere existence of pitches even seems

²⁰ Murail, T., programme note of *Le Partage des Eaux*, <http://www.tristanmurail.com/en/oeuvre-fiche.php?cotage=27533>, accessed 15 September 2010.

²¹ Ibid 20.

²² Ibid 20.

to be a nuisance for certain composers. I think it is time to reconsider the role of harmony and timbre within formal constructions – and this does not only apply to ‘spectral’ styles.²³

The above quotation from Tristan Murail sums up my own thoughts in regards to music and fixed media music in particular even though my search for harmony is slightly different from that of Murail and the spectral composers.

In instrumental music the idea of using an analysis of a sound spectrum and then composing a piece based on the material derived from the spectrum has been explored for nearly forty years by the so-called spectralist composers. Even though I was mostly inspired by composers such as György Ligeti, Mikael Edlund, Klas Torstensson and Jan W. Morthenson in my instrumental work *Ytspänning* (2010) and Denis Smalley in *Ti Chor*, there are some similarities to spectral composition that need to be addressed. Attempting to portray the history of spectral music is a task beyond the scope of this thesis and I would like instead, to draw parallels to my music and to that of Gérard Grisey, Tristan Murail and Kaija Saariaho in order to clarify my own aesthetic ambitions. Even though not thought of as a spectral composer, I would also like to include György Ligeti as his work are important to the development of instrumental composition based on timbral aspects.

Murail in his work *Désintégrations* (1982) for orchestra and fixed media structured his material by dividing the piece into eleven sections, each one based on a specific spectral treatment. The spectral content were based on the analysis of a certain instrumental sounds and each section transformed from an harmonic to an inharmonic spectra, or vice versa.²⁴

In *Utresa* (2003) I divided the piece into four major sections with fifteen subdivisions. Each section had a spectrum dominating the section and there would be a transformation from one section to the other through the different subdivisions (see Figure 2.52, page 101). My approach was more based on a traditional way of thinking with interval-based chords modulating from one chord to another rather than of change in timbre.

In *Ti Chor* the overall form was based on a modulation from an inharmonic spectrum to a harmonic spectrum, an idea used in reverse by Gérard Grisey in *Partiels* (1975). In Grisey’s

²³ Murail, T., ‘After-thoughts’, *Contemporary Music Review*, Vol. 19, Part 3, (2000), p. 9.

²⁴ Murail, T., ‘Spectra and Pixies’, *Contemporary Music Review*, Vol. 1, Part 1, (1984), p. 163.

piece the spectral development was a journey from a harmonic spectrum to white noise with the use of “instrumental synthesis”,

Analogous to the auditory synthesis used in the programmes of digital electronic music, this [instrumental synthesis] writing style uses the instrument (micro-synthesis) to express different elements of the sound and elaborate an overall sound form (macro-synthesis). The result of this treatment is that, for our perception, the different instrumental sources disappear to the advantage of a completely invented synthetic timbre. These different mergings allow for articulating and organising a whole range of timbres going from the spectrum of harmonics to white noise, by way of the different spectra of inharmonic partials.²⁵

The reason for using additive synthesis in the fixed media part of *Ti Chor* was (in addition to being able to transpose the scale steps correctly) to avoid the dilemma that Grisey mentioned in one of his lectures according to Anthony Cornicello, who writes,

“We were naïve then – each overtone was to be played by one of the instruments in the orchestra”,²⁶ meaning that there were little concern for the fact that each instrument does not produce a sine wave.²⁷

When I composed *Ti Chor* I was aware of the aesthetic concern of using instruments with an inherent harmonic spectra when composing spectrally with an inharmonic spectra. Hence the idea of modulation from inharmonic spectra to the harmonic and having the saxophones play mostly air noise or multiphonics during the first part of the piece, sounds that could be used without reference to traditional harmony. Towards the end of the piece, the saxophones played mixed techniques incorporating normal pitches when the modulation was completed.

Since then I have modified my aesthetics towards a less rigid approach in order to experiment with harmony, as did Grisey in the 1970s. Cornicello writes that,

the idea was not to replicate a sound that could be produced by an acoustic instrument, but to create new and unusual harmonies using spectra.²⁸

²⁵ Quotation from programme note: Grisey, G., ‘Interview with Guy Lelong’, translated by John Tyler Tuttle, *Les Espaces Acoustiques* (Kairos, 2005), 0012422KAI, p. 16.

²⁶ Cornicello, A., ‘Modulations and Chants de l’Amour’, Lecture notes from *Ircam Académie d’été*, Presented by Gérard Grisey, Ircam, Centre Georges Pompidou, Paris, France (23 June, 1998). Available from the author.

²⁷ Cornicello, A., *Timbral Organization in Tristan Murail’s Désintégrations and Rituals*, Graduate School of Arts and Sciences of Brandeis University, Waltham, Massachusetts, (May 2000), p. 37.

²⁸ Ibid 27.

In *Ytspänning* I did not apply the strict rules that I set up in *Ti Chor* and my compositional aesthetic was leaning more towards the idea of creating “new and unusual harmonies using spectra”, including the built-in harmonic spectra generated by stringed instruments. For example, in the string part I quantised the inharmonic partials of the analysed multiphonics to fit with pitches based on the harmonic spectrum, a completely different approach to that of *Ti Chor*. Some parts of *Ytspänning* were constructed with a kind of “instrumental synthesis”²⁹ as in “orchestrating” the spectrum (see Figure 1.2). My intention was however, not to *simulate* the sound of a multiphonic spectrum using string instruments. I used the frequencies that could be found in the analysed spectra in order to structure the pitch material and to achieve a connection between the strings and the saxophone. I did not expect complete fusion between the saxophones and the strings, an approximate similarity was considered to be enough as a total fusion was impossible anyway due to inherent harmonic complexity of the strings.

²⁹ Fineberg, J., ‘Guide to the Basic Concepts and Techniques of Spectral Music’, *Contemporary Music Review*, Vol. 19, Part 2, (2000), p. 85.

Quartet No. 2 (1968) (see Figure 1.3). It was the irregularity in pulse in combination with a perceived accelerando that I wanted and the method that Ligeti used in this section of his piece was a source of inspiration.

Figure 1.3: Opening bars of the third movement of Ligeti's *String Quartet No. 2* from 1968. Used with kind permission from the copyright holders (c) 1971 SCHOTT MUSIC, Mainz – Germany.

Exploring timbre through electronic devices is something that the spectralist composers have in common with Ligeti who worked with additive synthesis as a technique in his electroacoustic works in the 1950s and later in his instrumental pieces such as *Atmosphères* (1961)³⁰. Ligeti on the other hand was influenced by the early research in timbre that had taken place at the WDR Studio in Cologne, working side by side with Stockhausen, Herbert Eimert and Gottfried Michael Koenig in the late 1950s. Even though his work in the Cologne studio did not render more than a few fixed media pieces (*Glissandi* (1957), *Artikulation* (1958) and the unfinished work *Pièce électronique Nr. 3*), he changed the focus of instrumental composition by mapping electronic compositional techniques that he developed at the WDR studio in Cologne to his orchestral piece *Atmosphères*. Jennifer Iverson writes that,

In *Atmosphères*, Ligeti overcomes the difficulties of timbral synthesis due to cumbersome equipment, tape noise, inadequate numbers of synthesizers and time constraints of the mostly

³⁰ How additive synthesis influenced Ligeti in his piece *Atmosphères* is described in the research by Iverson, J. J., 'Historical Memory and György Ligeti's Sound-Mass Music 1958-1968', unpublished PhD Dissertation at The University of Texas at Austin, (2009).

manual studio work. He does so by mapping electronic compositional techniques into the acoustic realm, reclaiming the potential for timbre to play a primary role in shaping passages rather than simply remaining an effect.³¹

As Jennifer Joy Iverson concludes in her dissertation concerning Ligeti's music,

What is particularly remarkable about Ligeti's transference of electronic techniques to the acoustic realm, then, is the way it reawakens the potential for timbre to play a formative role in the compositional and aesthetic plan. [...]

Though having a good grasp of orchestration is also crucial in this respect, we should not underestimate the importance of the discourse around electronic compositional techniques, which brought timbre forward as the central compositional problem. In fact, Ligeti would not have been able to conceive of the timbral possibilities of the orchestra as he did in *Atmosphères* without having thought so carefully about and experimented with timbre in the Cologne studio.³²

Another composer who has developed the timbral possibilities of the orchestra is Kaija Saariaho. Inspired by Grisey's lectures on harmony and spectral music, Saariaho has in her music explored timbre and harmony³³. Saariaho writes that,

the function of timbre is considered as being vertical and that of harmony as horizontal. Harmony therefore provides the impetus for movement, whilst timbre constitutes the matter which follows this movement.³⁴

She continues:

On the other hand, when timbre is used to create musical form it is precisely the timbre which takes the place of harmony as the progressive element in music. It can also be said that these two elements become confused when timbre becomes an integral part of form and when harmony, by contrast, is confined to determining the general sonority.

In her piece *Verblendungen* for orchestra and fixed media (1982-1984), Saariaho used timbre and harmony as the main parameters and as a way to develop form. The timbre parameter would be the overall development from a noisy texture to a "quasi-orchestral luminosity made up of violin sounds" in the fixed media part with an opposite development in the orchestral part. The harmony parameter was constructed by using a chord consisting of all intervals possible within the chromatic scale (see Figure 1.4 and Figure 1.5).

³¹ Iverson, J. J., 'Historical Memory and György Ligeti's Sound-Mass Music 1958-1968', PhD Dissertation at The University of Texas at Austin, (2009), pp. 140-141.

³² Ibid 31.

³³ Beyer, A., 'Kaija Saariaho – Colour, timbre and harmony' from *The Voice of Music. Conversations with composers of our time*, Ashgate Publishing, London, (2001).

³⁴ Saariaho, K., 'Timbre and harmony: interpolations of timbral structures', *Contemporary Music Review*, Vol. 2, Issue 1, (1987), p. 94.

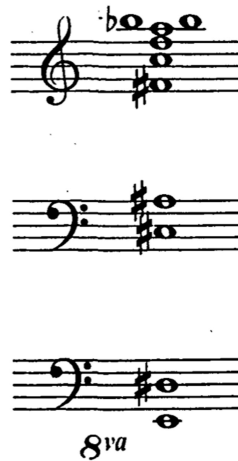


Figure 1.4. The basic chord of *Verblendungen*. All of the intervals are included in the chord.³⁵ Used with permission from the Taylor and Francis Group.



Figure 1.5. A concrete example of the principle of harmonic evolution in *Verblendungen*: the harmonic progression in the beginning of the piece³⁶. Used with permission from the Taylor and Francis Group.

In *Lichtbogen* (1985-1986) for ensemble and live-electronics, Saariaho continued to explore harmony and timbre, using the analysis of inharmonic sounds such as a cello playing a multiphonic sound obtained by increased bow pressure. She constructed harmonic progressions based on a “sound/noise” axis defining her own concept of consonance and dissonance. Saariaho writes that,

³⁵ From Figure 9 in Saariaho, K., ‘Timbre and harmony: interpolations of timbral structures’, *Contemporary Music Review*, Vol. 2, Issue 1 (1987), p. 108.

³⁶ From Figure 11 in Saariaho, K., ‘Timbre and harmony: interpolations of timbral structures’, *Contemporary Music Review*, Vol. 2, Issue 1, (1987), p. 109.

In an abstract and atonal sense the sound/noise axis may be substituted for the notion of consonance/dissonance. A rough, noisy texture would thus be parallel to dissonance, whilst a smooth, clear texture would correspond to consonance.³⁷

She compares the perception of tension related to a tonic to a noisy texture related to pure sounds, defining the pure sounds as akin to “the ringing of a bell or a human voice singing in the Western tradition”³⁸.

My research into harmony differs in the sense that I am concerned with a different definition of consonance than the one given by Saariaho due to the nature of fixed media. In the following text I will describe the research leading up to the results of my compositional practice based on psychoacoustical consonance and dissonance.

1.8: Consonance and Dissonance

The definitions of the terms consonance and dissonance have changed throughout the centuries and there is still confusion in their usage. In *A History of ‘Consonance’ and ‘Dissonance’*³⁹ James Tenney presents five different perspectives on how the terms have been used in history; melodic, polyphonic, contrapuntal, functional and sensory notions of consonance and dissonance. The first four terms describe consonance and dissonance from a functional perspective throughout the history of western tonal music. The last term describes consonance and dissonance from a psychoacoustic perspective and has nothing to do with structuring music in time.

It is therefore important to make a distinction between musical consonance and dissonance and psychoacoustic consonance and dissonance (which will be referred to as sensory consonance and dissonance).

It is also important to make clear that sensory consonance and dissonance plays a completely different role than the musical consonance and dissonance. As Norman Cazden writes in 1945,

³⁷ Saariaho, K., ‘Timbre and harmony: interpolations of timbral structures’, *Contemporary Music Review*, Vol. 2, Issue 1, (1987), p. 94.

³⁸ Ibid 37.

³⁹ Tenney, J., *A History of ‘Consonance’ and ‘Dissonance’*, White Plains, NY: Excelsior; New York: Gordon and Breach, (1988).

the ideas of sensory dissonance do not capture the functional idea of musical dissonance as restlessness of desire to resolve, and the linked notion of consonance as the restful place to which resolution occurs. In essence, it is the responsibility of the composer to impose motion from sensory dissonance and sensory consonance, if such a motion is desired.⁴⁰

There will be no attempts in this thesis to redefine already established terms like harmony, consonance and dissonance. The concern is rather to use research in psychoacoustics concerning sensory consonance and dissonance in order to compose music based on other principles than that of traditional harmony, exploring other ways of working with chords and new scales. When consonance and dissonance is mentioned from here on it will be implicit that it is in the meaning of sensory consonance and dissonance if not otherwise specified.

1.9: Sensory consonance and dissonance

Research concerning sensory consonance and dissonance has been a research topic for more than a century. A major breakthrough came when R. Plomp and W. J. M. Levelt published their article *Tonal Consonance and Critical Bandwidth* in 1965⁴¹. Plomp and Levelt's scientific experiments examined consonance and dissonance as a measurable psychoacoustical phenomena as opposed to a musical one. They carried out a number of experiments supporting Hermann von Helmholtz's⁴² theory published in 1863 regarding the notion that the phenomenon of consonance is related to "beats between partials" and "roughness". Plomp and Levelt used the term "tonal consonance" and found an important connection between von Helmholtz's beat theory and critical bandwidth, i.e. that the difference between consonant and dissonant intervals is related to beats between adjacent partials but also related to critical bandwidth.

The terms sensory consonance and sensory dissonance have since then been used to describe the same kind of auditory phenomenon related to beats between partials and auditory roughness and the listeners (both musicians and people with no musical training) perceived amount of "pleasantness" and "un-annoyance". Consonance is defined as absence of beats, perceived smoothness and pleasantness, and dissonance as presence of beats and perceived

⁴⁰ Cazden, N., 'Musical consonance and dissonance: A cultural criterion', *Journal of Aesthetics and Art Criticism*, Vol. 4, No. 1, (1945), pp. 3-11.

⁴¹ Plomp, R. & Levelt, W. J. M., 'Tonal Consonance and Critical Bandwidth', *Journal of the Acoustical Society of America*, Vol. 38, (1965), pp. 548-560.

⁴² von Helmholtz, H., *Die Lehre von der Tonempfindungen als physiologische Grundlage für die Theorie der Musik*, Verlag F. Vieweg & Sohn, Braunschweig, (1863), Chapter 2.

auditory roughness. Terms like “tonal consonance” and “psychoacoustic consonance” are also used. Psychoacoustic consonance was defined by Ernst Terhardt in 1974 as,

[...] keeping in mind that complex tones are composed of pure tones, the phenomenon of consonance seems to be covered by the definition: Consonance is the undisturbed simultaneous sounding of pure tones. The disturbing element which destroys consonance is roughness. The kind of consonance defined in this way will be called psychoacoustic consonance.⁴³

Based on the conclusion by Plomp and Levelt that intervals are consonant if no two partials lie within the same critical band, J. R. Pierce in 1966 presented an experiment showing that consonance could be obtained even with arbitrary scales containing unconventional intervals with sounds whose partials are other than simple ratios to the fundamental. Pierce concluded,

It appears that, by providing music with tones that have accurately specified but nonharmonic partial structures, the digital computer can release music from the tyranny of 12 tones without throwing consonance overboard.⁴⁴

In 1969 Akio Kameoka and Mamoru Kuriyagawa⁴⁵ presented mathematical formulae to calculate the rate of consonance of intervals depending on the partial structures of the two different sound sources. They explained why a certain fixed interval might have a different rate of consonance depending on the timbre of the musical instruments. They also showed that the rate of consonance is affected by change in amplitude (loudness). In the experiments carried out by Kameoka and Kuriyagawa a clear connection between the spectral content of a sound and consonance was made:

A theoretical investigation clearly showed that the consonance of chords is greatly dependent on the harmonic structure⁴⁶. Especially in the case of synthetic musical tones the effect is significant. The fifth (2:3), for example, is not necessarily a consonant interval. A complex tone that includes only odd harmonics shows consonant peaks at 3:5, 5:7, but not on the fifth (2:3).⁴⁷

⁴³ Terhardt, E., ‘Pitch, consonance, and harmony’, *Journal of the Acoustical Society of America*, Vol. 55, (1974a), pp. 1061-1069.

⁴⁴ Pierce, J. R., ‘Attaining consonance in arbitrary scales’, *Journal of the Acoustical Society of America*, (1966), p. 249.

⁴⁵ Kameoka, A. & Kuriyagawa, M., ‘Consonance theory, part I: Consonance of dyads’, *Journal of the Acoustical Society of America*, Vol. 45, No. 6, (1969a), pp. 1451-1459.

Kameoka, A. & Kuriyagawa, M., ‘Consonance theory, part II: Consonance of complex tones and its computation method’, *Journal of the Acoustical Society of America*, Vol. 45, No. 6, (1969b), pp. 1460-1469.

⁴⁶ The term “harmonic structure” used by Kameoka and Kuriyagawa = spectral content of a tone (in this case a tone with a harmonic spectrum).

⁴⁷ Kameoka, A. & Kuriyagawa, M., ‘Consonance theory, part II: Consonance of complex tones and its computation method’, *Journal of the Acoustical Society of America*, Vol. 45, No. 6, (1969b), p. 1469.

The experiments carried out by Plomp and Levelt, Kameoka and Kuriyagawa and others, clearly show that the degree of consonance is dependent on the spectrum of the sounds used. Even a sound with a harmonic spectrum might have a high degree of dissonance at certain traditionally consonant intervals depending on the amplitude of the interacting partials. In the experiment mentioned above made by Kameoka and Kuriyagawa, two sounds with harmonic spectra were used. One sound containing only odd partials was compared with a sound containing only even partials (see Figure 1.6).

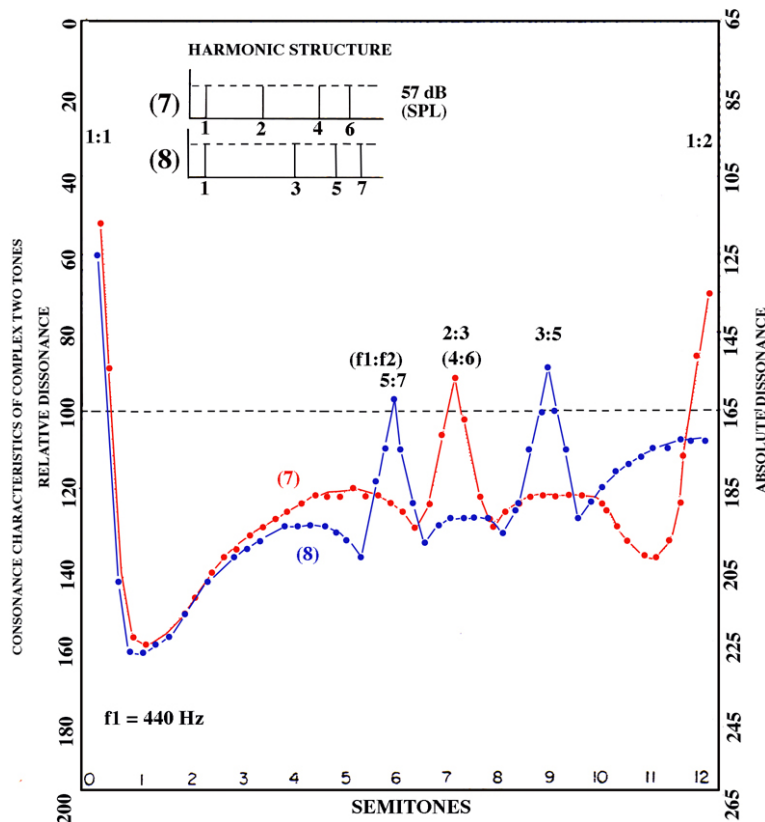


Figure 1.6. Experiment results reconstructed from Kameoka and Kuriyagawa⁴⁸.

The results from Figure 1.6 show that there are consonance peaks at the corresponding frequency ratios, i.e. that the sound with even partials (7) has a peak at the fifth (2:3) whereas the sound with odd partials (8) does not. This curve would be altered depending on what partials are included in the spectrum and also on the relative amplitude of the partials.

⁴⁸ Kameoka, A. & Kuriyagawa, M., 'Consonance theory, part II: Consonance of complex tones and its computation method', *Journal of the Acoustical Society of America*, Vol. 45, No. 6, (1969b), p. 1466, Fig. 9.

The results of this research question whether there is any psychoacoustic law stating that consonance is dependent on simple relationships in frequency. Could this mean that consonance is obtainable even for sounds with less regular relationships in frequency?

William A. Sethares in 1998 pointed out that the notion of sensory consonance and dissonance has two implications. Firstly, individual complex tones will have an intrinsic or inherent dissonance,

Since dissonance is caused by interacting partials, any tone with more than one partial inevitably has some dissonance. This is a stark contrast to all the previous notions, in which consonance and dissonance were properties of relationship between tones.⁴⁹

Secondly, that consonance and dissonance will depend not only on the interval between tones, but also on the spectrum of the tones used,

Since intervals are dissonant when the partials interact, the exact placement of these partials is crucial.⁵⁰

The latter is something that Pierce was already aware of more than thirty years earlier when working with his arbitrary scales and correlating sounds⁵¹.

Based on these experiments, my compositional research then looked how sounds with other kinds of spectral relationships work together to derive a new sense of harmonic consonance and dissonance.

1.10: Consonance and dissonance curves

In 1747 the German organist, composer and theorist Georg Andreas Sorge presented for the first time the idea that beating of partials causes dissonance⁵² and more than a century later von Helmholtz introduced the first visual representation of a dissonance curve, a roughness curve based on two violins. Based on the results from one violin playing a fixed note on C and the other violin sliding up slowly, Helmholtz came to the conclusion that intervals described by small number of ratios are maximally consonant.

⁴⁹ Sethares, W. A., *Tuning, Timbre, Spectrum, Scale*, Springer-Verlag London Limited, (1998), p. 75.

⁵⁰ Ibid 49.

⁵¹ Pierce, J. R., 'Attaining Consonance in Arbitrary Scales', *Journal of the Acoustical Society of America*, Vol. 40, No 1, (1966), p. 249.

⁵² Sorge, G. A., *Vorgemach der musicalishen composition*, 3 volumes, Verlag des Autoris, Lobenstein, (1745-1747).

It will be seen that the various roughnesses arising from the different intervals encroach on each other's regions, and that only a few narrow valleys remain, corresponding to the position of the best consonances, in which the roughness of the chord is comparatively small.⁵³

The result of the experiment was the roughness curve as seen in Figure 1.7. The curve shows that minimal dissonance occurs at the “valleys” that belong to the octave (c’’) and the fifth (g’). Then comes,

the Fourth f’, the major sixth a’, and the major Third e’, in the order already found for these intervals. The minor Third e’ flat and the minor Sixth a’ flat, have ‘cols rather than valleys, the bottoms of their depressions lie so high, corresponding to the greater roughness of these intervals.⁵⁴

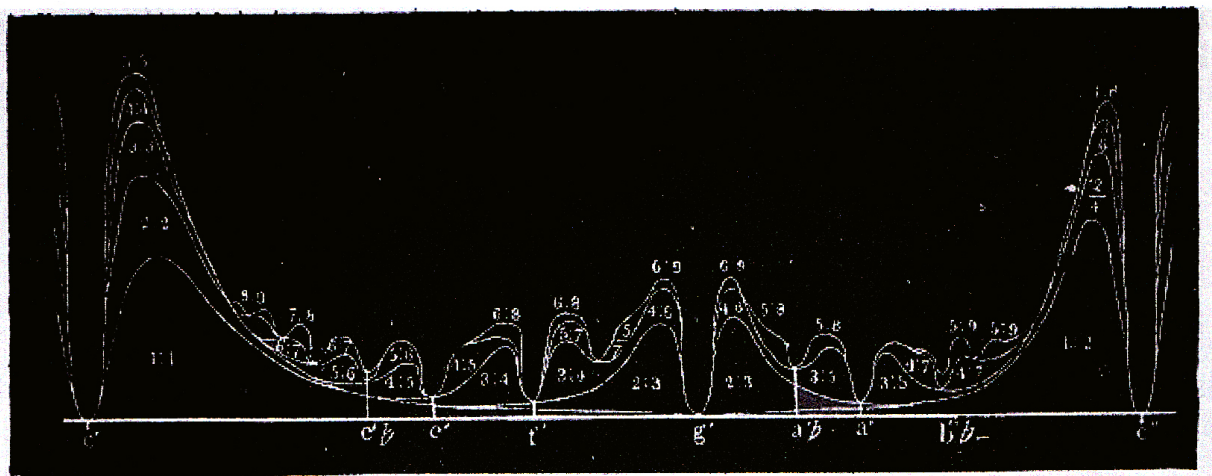


Figure 1.7. Helmholtz’s roughness graph (Figure 60 A) from *On the Sensations of Tone* (1877).

Composer and theorist Harry Partch begins chapter nine in his *Genesis of a Music* with the following words,

According to Galileo, “agreeable consonances are pairs of tones which strikes the ear with a certain regularity; this irregularity consists in the fact that the pulses delivered by the two tones, in the same interval of time, shall be commensurable in number, so as not to keep the eardrum in perpetual torment, bending in two different directions in order to yield to the ever-discordant impulses.”⁵⁵ The fairly “perpetual” torment which is our heritage in Equal Temperament has long obscured this aural axiom.⁵⁶

⁵³ von Helmholtz, H., *On the Sensations of Tone*, (1877). Trans. A. J. Ellis, Dover, New York (1954).

⁵⁴ Ibid 53.

⁵⁵ Miller, D. C., *Anecdotal History of the Science of Sound: To the Beginning of the 20th Century*, New York, The MacMillan Company, (1935).

⁵⁶ Partch, H., *Genesis of a Music – an account of a creative work, its roots and its fulfilments*, Second Edition, Da Capo Press, New York, (1974), p. 138.

Here he presents his ‘One-Footed Bride’ - a rough graph of comparative consonance (see Figure 1.8).⁵⁷

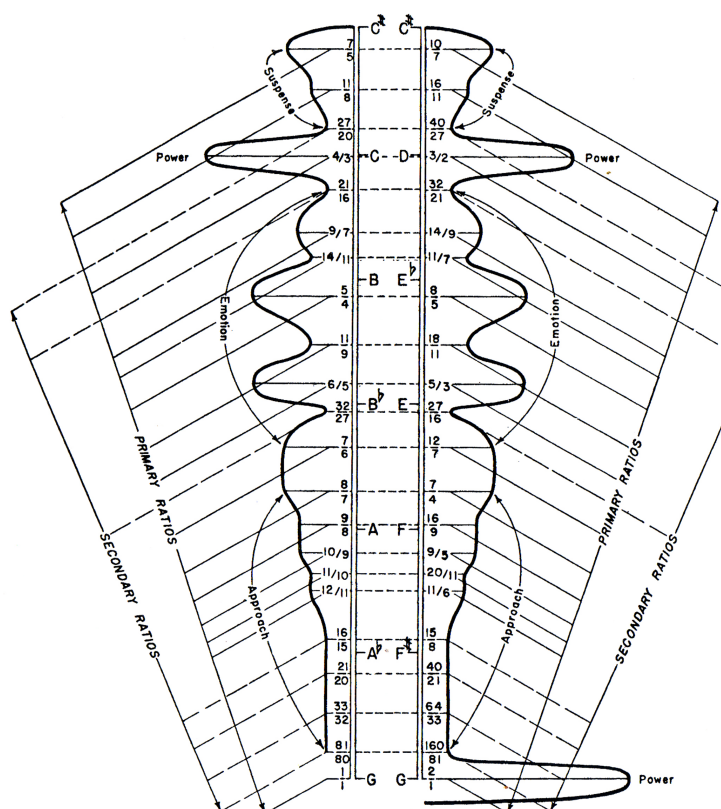


Figure 1.8. The One-Footed Bride: A Graph of Comparative Consonance. From Diagram 8 in *Genesis of a Music*. Used by kind permission from The University of Wisconsin Press.

Partch’s work and research is based on a tradition dating back to the ancient Greeks, the Pythagoreans and Ptolemy in particular, through music theorists and mathematicians such as Zarlino, Rameau, Galileo, Kepler, Helmholtz until the early 1900s. Partch was interested in creating music based on scales with more than 12 notes per octave. He built his own instruments, such as the “Chromelodeon”, a reed organ, in order to play the music he had composed with a scale with 43 scale steps per octave.

He tuned his reed organ with “no other aid than the ability of the ear to distinguish pulsations ‘commensurable in number’ and those which bend its tympanum ‘in two different directions’”⁵⁸ in this 43 tone per octave scale with the focus on Just Intonation. By doing this

⁵⁷ Partch, H., *Genesis of a Music – an account of a creative work, its roots and its fulfilments*, Second Edition, Da Capo Press, New York, (1974), p. 155.

⁵⁸ Partch, H., *Genesis of a Music – an account of a creative work, its roots and its fulfilments*, Second Edition, Da Capo Press, New York, (1974), p. 138.

he, as summarised by Sethares, “classified and categorised all the 43 intervals in terms of their comparative consonance”.⁵⁹

A consonance curve portrays the perceived consonance and dissonance versus musical intervals. Helmholtz’s roughness curve⁶⁰, Plomp and Levelt’s consonance curve⁶¹ as well as Partch’s “One Footed Bride”⁶² are examples of dissonance curves.

All of these dissonance curves show how the ear perceives sounds with harmonic or no (pure sine tones) spectra as sensory consonant at certain traditionally “consonant” scale steps, if the scale is tuned in Just Intonation (rather than the equally tempered tuning). The points of maximum sensory consonance occur on these scale steps, which shows the correspondence between spectrum and scale.

Sethares’ dissonance curve is however, mathematically constructed to portray the perceived consonance and dissonance versus musical intervals with sounds containing *any* spectra. A comparison with Sethares’ dissonance curve (Figure 1.10) and an experiment carried out by Kameoka and Kuriyagawa⁶³ show that Sethares’ calculations are related to the results of their experiment (Figure 1.9).

In Kameoka and Kuriyagawa’s third experiment presented in 1969, chords of two identical complex tones were used. One of the tones containing eight partials was fixed at 440 Hz and the other tone was played together with the first from 440 Hz to 880 Hz (an octave) divided into fifteen steps. The degree of dissonance was calculated for each step according to the circles seen in Figure 1.9. The results from the experiment showed that the degree of consonance and dissonance seemed to occur on the same minima and maxima steps that were calculated in advance.

⁵⁹ Sethares, W. A., *Tuning, Timbre, Spectrum, Scale*, Springer-Verlag London Limited, (1998), p. 83.

⁶⁰ Helmholtz, H., *On the Sensations of Tone*, (1877). Trans. A. J. Ellis, Dover, New York, (1954).

⁶¹ Plomp, R. and Levelt, W. M., ‘Tonal consonance and critical bandwidth’, *Journal of the Acoustical Society of America*, Vol. 38, (1965), pp. 548-560.

⁶² Partch, H., *Genesis of a Music*, Da Capo Press, New York, (1974).

⁶³ Kameoka, A. & Kuriyagawa, M., ‘Consonance theory, part II: Consonance of complex tones and its computation method’, *Journal of the Acoustical Society of America*, Vol. 45, No. 6, (1969b), pp. 1464-1465.

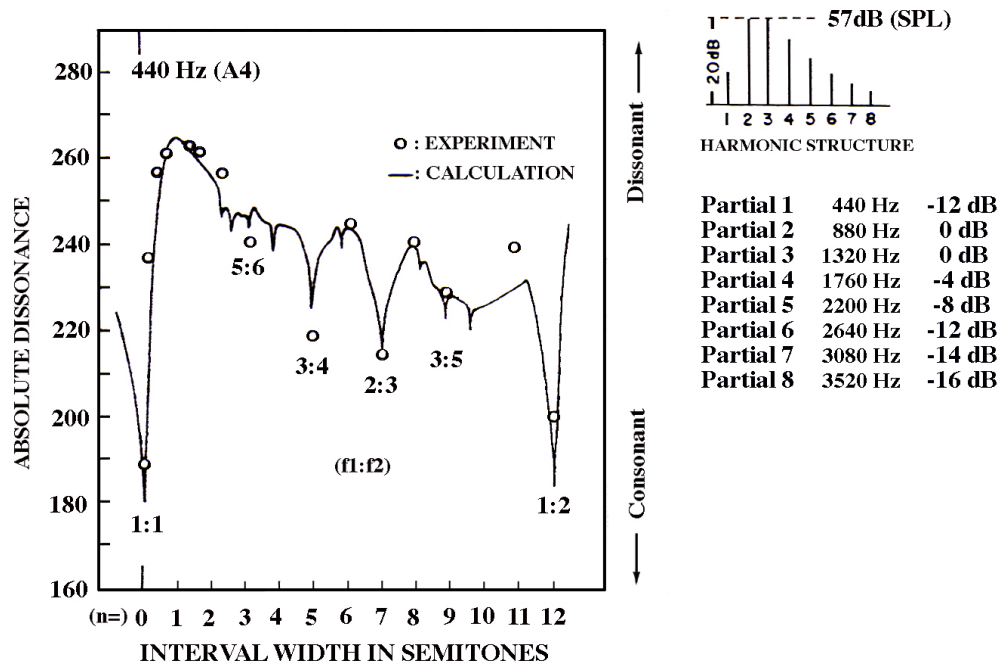


Figure 1.9. Kameoka and Kuriyagawa's experiment where chords of two identical complex tones were used. The solid line represents the calculated values, and the circles represents the experimental values. The graph is turned upside-down compared to the original in order to clarify the similarities between Sethares' calculations.

In order to compare with Sethares' dissonance curve I used the same partials and respective amplitudes as Kameoka and Kuriyagawa used in their experiment and explored what the results would be if used with Sethares' algorithm. I turned the graph of the Kameoka and Kuriyagawa experiment upside down with the y-axis portraying the degree of dissonance instead of consonance so that the two graphs could be compared. The result was that both dissonance curves showed minima and maxima steps in the same places. My conclusion was then that Sethares' dissonance curve agreed with Kameoka and Kuriyagawa's research.

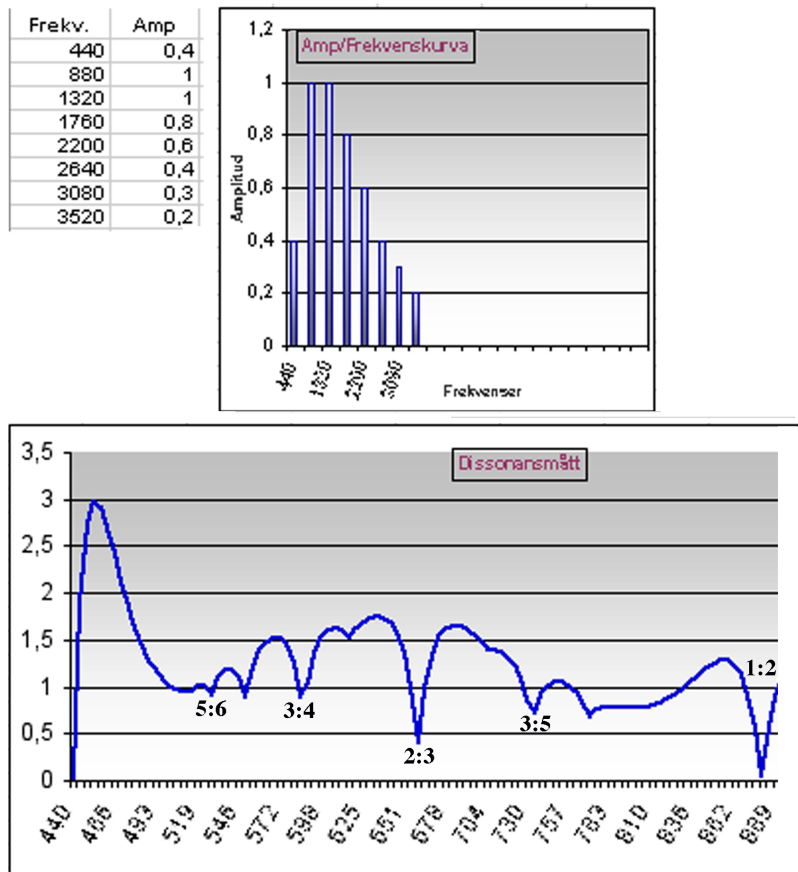


Figure 1.10. Sethares' dissonance curve using the same input as Kameoka and Kuriyagawa's experiment (see Figure 1.9).

Sethares states that “a spectrum and a scale are related if the dissonance curve for the spectrum has minima at the scale steps”⁶⁴. Sethares' dissonance curve allows further investigation concerning the relationship between inharmonic spectra and scales. His approach is that:

The idea of relating spectra and scales is useful to the electronic musician who wants precise control over the amount of perceived dissonance in a musical passage. For instance, nonharmonic sounds are often extremely dissonant when played in the standard 12-tet tuning. By adjusting the intervals of the scale, it is often possible to reduce (more properly, to have control over) the amount of perceived dissonance. It can also be useful to the experimental musician or the instrument builder. Imagine being in the process of creating a new instrument with an unusual (i.e., non-harmonic) tonal quality. How should the instrument be tuned? To what scale should the finger holes (or frets, or whatever) be tuned? The correlation between spectrum and scale answers these questions in a concrete way.⁶⁵

Sethares' research is based on using the original, analysed sound as the basic sound material for a piece. Therefore he suggests creating a “virtual” instrument:

⁶⁴ Sethares, W. A., *Tuning, Timbre, Spectrum, Scale*, Springer-Verlag London Limited, (1998), p. 89.

⁶⁵ Sethares, W. A., *Tuning, Timbre, Spectrum, Scale*, Springer-Verlag London Limited, (1998), p. 90.

Sound begins in a digital sampling keyboard (a sampler) as a waveform stored in a computerlike memory. This is processed, filtered and modulated in a variety of ways, and then spread across the keyboard so that each key plays back the “same” sound, but at a different fundamental frequency.⁶⁶

The idea of working with only one initial complex sound differs from the idea for my works as will be discussed later on. It is from here Sethares’ research has little or no relevance for this thesis. However, the dissonance curve is used as a tool in order to explore new harmony, to work with intervals based on inharmonic spectra in both a linear and vertical manner - as a melodic scale as well as sensory consonant chords.

1.11: How to establish sensory consonance

Sethares summarizes with reference to Norman Cazden, that sensory consonance and dissonance plays no role concerning the important aspects of musical movement. Traditional functional musical consonance does, but is irrelevant when composing with sounds with a spectrum that differs from those with simple integers (harmonic spectrum) and with scales that are constructed from these non-harmonic spectrums.

However, the notion of creating a whole *new* functional musical consonance based on new scales and spectrum is an appealing thought, but beyond the scope of this thesis. Therefore the task has been to explore different scales constructed from the spectrum of non-harmonic sounds and to see how these scale steps work together when played as chords. The idea has also been to use the scale steps and chords as a way of structuring the harmonic development in my pieces.

A musical interval is generally considered to be consonant if it sounds pleasant or restful; a consonant interval has little or no musical tension or tendency to change. Dissonance is the degree to which an interval sounds unpleasant or rough; dissonant intervals generally feel tense and unresolved.⁶⁷

In order to create a harmony based on an inharmonic spectrum, the first step was to look into how to establish some kind of consonance. This was needed in order to structure the sound material on a vertical axis, as chords. In order to use chords, there needed to be a way of

⁶⁶ Sethares, W. A., *Tuning, Timbre, Spectrum, Scale*, Springer-Verlag London Limited, (1998), p. 130.

⁶⁷ Sethares, W.A., ‘Local consonance and the relationship between timbre and scale’, *Journal of the Acoustical Society of America* 94, (3), Part 1, (September 1993), p. 1218.

creating intervals so that when played at the same time they would interact in a sensory consonant manner. Creating sensory dissonant chords is no challenge but to create a chord based on two or more sounds with an inharmonic overtone spectrum that is not perceived as sensory dissonant is. It is here Sethares' dissonance curve was a helpful tool to explore further the correlation between inharmonic spectra and sensory consonance.

Sethares suggests in his research related to tuning and scales that one must do the following to get the most accurate results from the dissonance curve:⁶⁸

- A - Choose a sound
- B - Find the spectrum of the sound
- C - "Simplify" the spectrum
- D - Draw the dissonance curve and choose a set of intervals (a scale) from the minima
- E - "Create an instrument" that can play the sound at the appropriate scale steps
- F - Play music

Items "A" to "D" also work as a starting point for *Utresa*, *Joker*, *The Ringing Stone of Håga* and *Echo in Silence*. The pieces then further explore how to develop music using Sethares' dissonance curve as part of the first stage of the compositional process.

⁶⁸ Sethares, W. A., "Tuning, Timbre, Spectrum, Scale", Springer-Verlag London Limited, (1998), p. 124.

Chapter 2 – Commentary on the Works

2.1 *Ti Chor* (1999)

- saxophone quartet (soprano, alto, tenor, baritone) and fixed media: 8'50

Ti Chor is a piece for saxophone quartet and 4-channel tape and was composed for the four Swedish musicians in The Stockholm Saxophone Quartet (Figure 2.1) to be performed at the Stockholm Electronic Music Festival in Sweden in 1997. Since then the composition has been re-worked and the revised, shortened edition was completed in 1999.



Figure 2.1. The Stockholm Saxophone Quartet. From left to right: Sven Westerberg, Leif Karlborg, Per Hedlund, Jörgen Pettersson. Photo used with permission from Mats Möller.

Ti Chor focuses on exploring harmony based on the spectral content of the sounds of multiphonics from saxophones.

Concept and method

One of the concepts for the work was to integrate closely the spectral content of the fixed media part with the instrumental in order to create a perceptual ambiguity during performance.

The method used to achieve this was to sample the saxophones and use these recorded sounds in the fixed media part together with new sounds created by means of additive synthesis based on the spectral content of the multiphonics.

The main idea in the work was to create scales and then melodic figures extracted from the spectrum of the multiphonics played by the saxophones. Modulations would then be made between these different multiphonics throughout the composition. In order to do this, a set of multiphonics were chosen based on their pitch content taken from Daniel Kientzy's "Les Sons Multiples Aux Saxophones"⁶⁹ and tested with the assistance of the Stockholm Saxophone Quartet.

The harmonic structure underlying the piece is a transformational process from inharmonic to harmonic spectra.

Compositional process and sound material

In order to link closely the instrumental part with the fixed media part I analysed the spectrum of the saxophones as they played the set of pre-chosen multiphonics. After trying them out, thirteen specific multiphonics were chosen considering their pitch content and the musicians' ability to play them (the saxophonists were instructed to start with the chosen multiphonic, then resolve to one partial, returning again to the original multiphonic without pausing). After recording the multiphonics, the next step was to analyse them spectrally using the software Alchemy. Then melodies (or more accurately scales) were derived from the analysed spectrum of each one of the multiphonics.

The overall structure was based on the progression of these melodies as they modulated from one multiphonic to another throughout the piece (see Figure 2.2). The tape part consisted mostly of sounds made with additive synthesis. Using synthesis was a practical necessity in order to be able to transpose correctly the melodies derived from the different multiphonic spectra.

Other materials used were edited sounds from recordings of the saxophones, used in a way so that the listener would have a difficulty knowing if the sounds they heard came from the musician or from the tape. In order to avoid sounds that would have a reference to traditional

⁶⁹ Kientzy, D., "Les Sons Multiples Aux Saxophones", Editions Salabert E.A.S. 17543, ISMN M 048 00364 4, 1982, (republished 2000).

music based on the well-tempered 12-tone system I used other extended playing techniques played by the saxophones apart from the multiphonics.

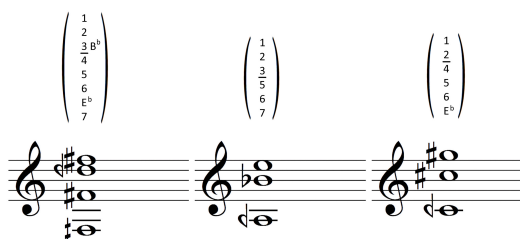


Figure 2.2. In *Ti Chor* the compositional process begins with the idea of composing a piece where the tape part would be closely linked and an equal part (like a 5th musician) to the saxophone quartet. Some multiphonics sounds were chosen, tried out and recorded and were used as the musical structure (M). The analyses of the chosen sounds were then used to construct the overall form of the piece in time and the harmonic progressions throughout the composition (T+H). The sound material in both the tape part and in the instrumental, were edited and shaped to work with T+H.

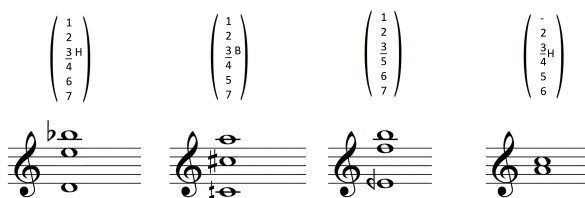
The musical structure and its effect on the time-domain and the harmonic progression

In *Ti Chor* the material is closely integrated in the form and vice versa. The basic sound material (the saxophone multiphonics) was chosen based on its pitch content and after analysing the material in *Alchemy* the overall form was refined based on the results and in the end only nine of the thirteen multiphonics were used. The form is based on harmonic progressions throughout the composition.

The piece is roughly divided into three sections: The first part is based on the spectrum of the three alto and two of the soprano multiphonics (see Figure 2.3):



Three alto multiphonics notated in C.



Four soprano multiphonics notated in C.

Figure 2.3. Alto and soprano multiphonics used in *Ti Chor*.

The second part is based more on noise sounds and the spectrum of three of the soprano multiphonics and of two of the baritone multiphonics. The third part is mixture of alto, soprano and baritone multiphonic spectra ending with more harmonic-pitched material.

The composition begins with a presentation of the three multiphonics played by the alto saxophone, one at a time, and then two multiphonics played by the soprano saxophone (see Figure 2.4). The melody is heard in the fixed media part and the other saxophones play pitched noise with notes that exists in the alto multiphonic and its transpositions. Between each multiphonic there is a modulation/transition to the next spectrum.

The image shows a musical score for a piece titled "Ti Chor" by Pauline Sandron. The score is written for five parts: Soprano saxophone (Sop sax), Alto saxophone (Alt sax), Tenor saxophone (Ten sax), Baritone saxophone (Bar sax), and Tape (2-C). The tempo is marked as 1 = 60. The score includes various musical notations such as notes, rests, and dynamic markings like "pp" and "p". The Alto saxophone part is particularly prominent, showing a series of notes that correspond to the multiphonic sounds described in the text. The Tape part (2-C) also shows a series of notes that correspond to the melody extracted from the multiphonic sounds.

Figure 2.4. From the first page of the transposed score of *Ti Chor*. The alto saxophone plays the multiphonic that the tape part has extracted its melody from. The musician alters between the whole range of the multiphonic to different single partials. The soprano, tenor and baritone saxophone play pitched noise.

Linear approach to scales

In *Ti Chor* the scales were constructed based not on their horizontal properties but on their linear qualities. The scales were not meant to be used as chords but as melodies. The idea is derived from non-western music like traditional Indian ragas and Arabic traditional music in the sense that they are based on micro-tonality with a linear approach not designed for chords, than that of the tempered 12th tone scale which is a mathematical construction designed to work in both a linear and vertical way.

The method for extracting the melodies in *Ti Chor* was to analyse the multiphonics of the saxophones in *Alchemy*, choose the eight first (strongest in amplitude) partials and also the 13th partial for each of the thirteen multiphonics. The idea was to use partial 1, 2, 3, 5, 8 and 13 as a scale/melody. The chosen partial numbers for the melody were based on the Fibonacci series⁷⁰.

After the analysis the index for the relationship between the partials was calculated. For example, multiphonic no. 2 from the alto saxophone set (Figure 2.5) had the following spectral content and ratio between the partials (index):

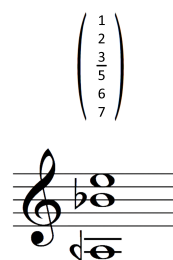


Figure 2.5. The second alto multiphonic notated in C.

Partial No.	Frequency	Index
13	2953 Hz (\approx F#)	1.631428865
8	1810 Hz (\approx A)	1.131239021
7	1600 Hz	1.182541675
6	1353 Hz	1.188911752
5	1138 Hz (\approx C#)	1.234252874
4	922 Hz	1.371989659
3	672 Hz (\approx E)	1.445119413
2	465 Hz (\approx A#)	2.214147194
1	210 Hz (\approx G#)	(Fundamental)

A melody/scale with six notes based on transpositions of partial no. 1, 2, 3, 5, 8 and 13 (Figure 2.6) was calculated. The partials were transposed down one or more octaves in order to create a melody within an octave and then sounds were created with additive synthesis containing nine partials (of strong amplitude) in the spectrum (Figure 2.7). The additive synthesis was made in the software program Turbosynth and as the process of making the

⁷⁰ A sequence of numbers in which each is the sum of the previous two, thus: 0, 1, 1, 2, 3, 5, 8, 13, 21, 34 etc. Tatlow, R., *Grove Music Online*, Oxford University Press, (2007-2010). Accessed 7 August 2010.

new sounds was time consuming I limited the amount of number of partials to be used in the additive synthesis to a maximum of nine. Whilst creating the additive synthesis I aurally judged for each sound how many partials that were needed in order to resemble the timbre of the original multiphonic.



Figure 2.6. An approximate note representation of the melody derived from the spectrum of the no 2 alto multiphonic. The six notes were based on partial no. 1, 2, 3, 5, 8 and 13 transposed to fit within one octave.

For comparison: The first transposition, partial no. 2, had the following spectral content when transposed an octave down (chord number 2 in Figure 2.7):

Partial No.	Frequency
13	3260 Hz (\approx G#)
8	1998 Hz (\approx B)
7	1767 Hz
6	1494 Hz
5	1256 Hz (\approx D#)
4	1018 Hz
3	742 Hz (\approx F#)
2	514 Hz (\approx C)
1	232 Hz (\approx A#)

(Partial no. 2 from the original spectrum transposed an octave down)



Figure 2.7. The additive synthesis consisted of partials 1, 2, 3, 4, 5, 6, 7, 8 and 13 from the analysis of the original multiphonic spectrum. Here is the content in the additive synthesis for the melody derived from the second alto multiphonic, transposed for each note in the melody (which as mentioned before was derived from partials 1, 2, 3, 5, 8 and 13).

A melody of six notes for each multiphonic (see Appendix 2) was created this way and they were used as a basic material in the fixed media part of *Ti Chor*.

Performance

The score was notated with a tempo of crotchet = 60 in 4/4 so that it would work as a “sekundpartitur” with a fourth note equal to one second. The original tape part was composed for 4-channels mixed on to an A-DAT with a 5th track consisting of SMPTE-code that controlled a light with two colours. The first beat of the bar was programmed to trigger a red light and the three remaining beats with a green light. All the saxophone players had visual contact with the light and were able to follow the score.

Depending on the concert hall during various performances, different reverbs were used on the sounds coming from the saxophone players through microphones. The idea was to enhance the perceptual ambiguity during performance by mixing the sounds of the fixed media with the sounds from the instruments in the loudspeakers.

Evaluation

Ti Chor is the first piece where I worked consciously with inharmonic spectra and allowing it to impact not only on the sound material used but also on the harmonic progression of a piece. When *Ti Chor* was finished I wanted to explore other ways of working with harmony, finding a way of combining a linear approach with a chordal approach, i.e. looking for a possibility to construct chords that sound “not too dissonant” if they were based on an inharmonic spectrum. I wanted to select sounds with an inharmonic spectra and analyse them in another software program, Audiosculpt, look at formant frequencies, partials and their amplitudes and from there calculate how their particular spectras were constructed. I then wanted to look for an “octave”, whatever the ratio might be (not 2:1 but perhaps 2.7:1 or 3.2:1 etc.). When the scale was constructed, I wanted to use it to see if it was possible to construct chords that sound not too dissonant if experimented with in different “keys”.

At this point I was not aware of the research made by W. A. Sethares et al in the psychoacoustic field, I knew what I was looking for but did not yet have knowledge about psychoacoustic consonance and dissonance.

A desire to explore new harmonic concepts was emerging but there were other paths I needed to explore first.

The compositional idea in the case of *Ti Chor* was based on sounding material (the recorded multiphonics) with no non-musical references. Could a non-musical idea be a constructive way of structuring the material in a composition without the non-musical idea being audible or perceived in the music?

2. 2 *Reflections* (1999)

- fixed media in stereo, 8-channel and 12-channel: 9'00

Reflections is a collaborative piece, composed together with the Swedish composer Jens Hedman in 1999 at EMS in Stockholm. The 8-channel version of *Reflections* was composed for a concert tour with the theme “Life and Death”, visiting churches around Sweden in 1999. The 12-channel version was mixed for the outdoor loudspeaker sculpture *Elektrofonen* (see Figure 2.8). *Reflections* is included in the portfolio as an example of a collaborative compositional process in which I have been involved. It also presents the method of mixing stereo pieces to multi-channel that I have used in many later compositions.



Figure 2.8. The 12-channel loudspeaker sculpture *Elektrofonen* created by Jens Hedman and Christian Hörgren.

Concept and method

With *Reflections* we wanted to compose a fixed media piece based on material that had been used in an earlier collaborative work – the soundtrack to the computer-animated video *Inside Round*.

The music for *Inside Round* was intended to be of equal importance as the video, sometimes complementary, sometimes autonomous. Its most important role was however, to support the computer animation as a soundtrack. As such it had a clear mimetic reference to the visual images.

The programmatic idea for *Reflections* was based on the theme “Life and Death” as an aspect of human life - “a symbolic journey, a reflection of life, travelling from birth towards death and purity”.⁷¹ We thought that some of the musical material from the video had potential to work with this programmatic idea and that is why we wanted to use material from *Inside Round*.

Compositional process

In *Inside Round* the sounds were linked to the animation and with a few exceptions the sound material of the piece was adjusted to the time-grid of the video. The visual image (V) structured the placement of sounds in time (T) as seen in Figure 2.9.

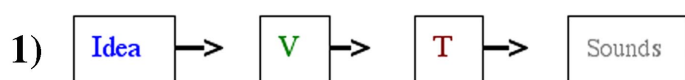


Figure 2.9. A simplified model of the compositional process of *Inside Round* in time.

In *Reflections* certain sections from *Inside Round* were re-worked and used, others cut but the piece retained approximately the overall form from the soundtrack with a similar beginning, middle and end. One of the things we worked with was to adjust parts of the *Inside Round* material for “musical time” as musical events in time might be perceived differently if connected with a visual media. Completely new sections such as the material heard in 4’47-5’14 were composed for *Reflections*. We continuously listened to mixes of *Reflections* from

⁷¹ An excerpt from the programme note of *Reflections* (1999).

start to end allowing new material to adjust the pace and placements of events in time (T) (see Figure 2.10).

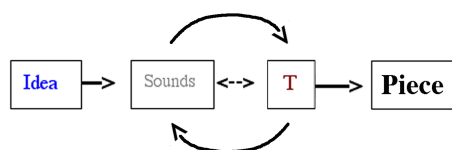


Figure 2.10. A simplified model of the compositional process of *Reflections* in time.

The sound material

Most of the sound material for *Reflections* was made in 1995 for the video *Inside Round*. The sound material used consisted mostly of recordings of metal plates and instruments, paper, cardboard boxes, plastic cups, keys, trains, water and acoustic feedback. Synthesised sounds made with the Buchla analogue synthesizer and in the software program Turbosynth were also used. The sounds were processed in software programs such as ProTools, Sound Designer, SampleCell, Turbosynth, Soundhack and hardware such as the Lexicon 300 reverb unit and Roland RSS-10 Sound Space Processor. The Swedish National Radio's SSL-mixing desk was used as a process tool to mix from DAT to a digital 16-channel tape.

Many sound gestures were a direct result of the video artist's wishes for "Mickey-Mousing"⁷²-effects and they were later used in *Reflections* as they were considered to be musically interesting. An example of one of these gestures (as can be heard in the piece at 4'24, 4'33, 4'43 and between 5'13-5'38) was the attack-like sounds, "bangs", that correlated visually to a computer-animated ball trapped in a closed square room, throwing itself against the walls, floor and ceiling. The sound materials that were used to create these attack gestures were made out of several sounds that were all placed spatially with the help of surround recordings or surround software in the musical space. For instance, when the animated ball hit the ceiling (at 4'33) we recorded sounds with a Neumann dummyhead microphone (a binaural stereo microphone), standing on the floor while metal plates and other sound objects were hit high above it.

The characteristics of the processed sounds used were for the most part:

⁷² Mannerfeldt, N., 'Mickey mousing - och sedan då?: något om musikens roll i tidiga animerade kortfilmer från Walt Disney Studios', *Musikologen*, Uppsala University, The Department of Musicology, (1992), pp. 23-29.

1. Long background sounds created by mixing many layers of sounds together
2. Short sounds for the gestures created by mixing even shorter sounds together
3. Clear in frequency (extreme low bass in contrast to extreme high frequency sounds, etc).

The connection with the visual image

In order to describe the music in *Reflections* a description of how the sound material was developed during the work with *Inside Round* is necessary. The programmatic idea behind *Inside Round* was,

about the mind, flabbergasted in the face of existential absurdity. Reflecting upon the outside ongoing life it is exposed to and being an isolated world of its own at the same time. [...] ⁷³

In order to portray this, the visual image in *Inside Round* was divided into five parts. Part one began with travelling through a computer-animated tunnel leading to an empty room with three windows: two in the side walls and one in the rear wall. In the side window crowds of people passing by, city life, and abstract images were presented. In the rear window was the image of a single person staring into the empty room.

The idea was to achieve contrast between,

the drama of outside ongoing life that we are exposed to and the state of the human mind reflecting that life and being an isolated world of its own at the same time. ⁷⁴

The empty room represented the mind itself.

The sounds illustrating the journey through the tunnel can be heard at the beginning of *Reflections* until 1'32.

In part two the windows disappeared to create visual “silence”. The silence was portrayed musically with a theme made out of acoustic feedback heard at 1'32 in *Reflections*. Then, in the video the head of the person in the rear window turned into a ball.

The ball takes off from the body and slowly expanding, enters the room. The image on the person's head (face only) is mapped on the ball's surface. The ball rotates, the head talks; the

⁷³ An excerpt from the programme note of *Inside Round*. Concept and image: Dinka Pignon.

⁷⁴ Excerpt from mail with Dinka Pignon 1995-07-04.

sound and the image follow the rotation (circulating sound-effect). When the head has said all its lines the image disappears and the ball falls heavily to the floor.⁷⁵

Parts of the music illustrating the above were used in *Reflections* from 1'32 until 4'02 when the sound of the ball falling to the floor ended this section.

In part three we worked a lot with the movement illustrating the following:

The ball moves unpredictably (as if it was effected by a powerful but unstable gravitational field in the room): it levitates, rotates, bangs against the walls; it contrasts, expands and changes texture. Towards the end the room as well starts changing its form and after a chaotic climax everything suddenly stops.⁷⁶

When we worked with sections where the timing between the visual image and the music needed to be exact we had to rely on time code on paper, as we did not at the time have access to a studio where we could work with image and sound at the same time. Pignon worked on the computer animation at the Royal University College of Fine Arts in Stockholm parallel to Hedman and I working on the music at EMS. Figure 2.11 shows a sketch with time code for how the ball would rotate in the image in part three and in Figure 2.12 timings for where and when the ball would hit the walls, ceiling and floor as shown. Hedman and I then used this information as a time grid in Dyaxis (mixing software) in order for the music to match the animation. It was not until both the computer animation and the music were finished and mastered at a post-production studio that we were able to tell if the timing would work or not.

⁷⁵ Excerpt from mail with Dinka Pignon 1995-07-04.

⁷⁶ Ibid 75.

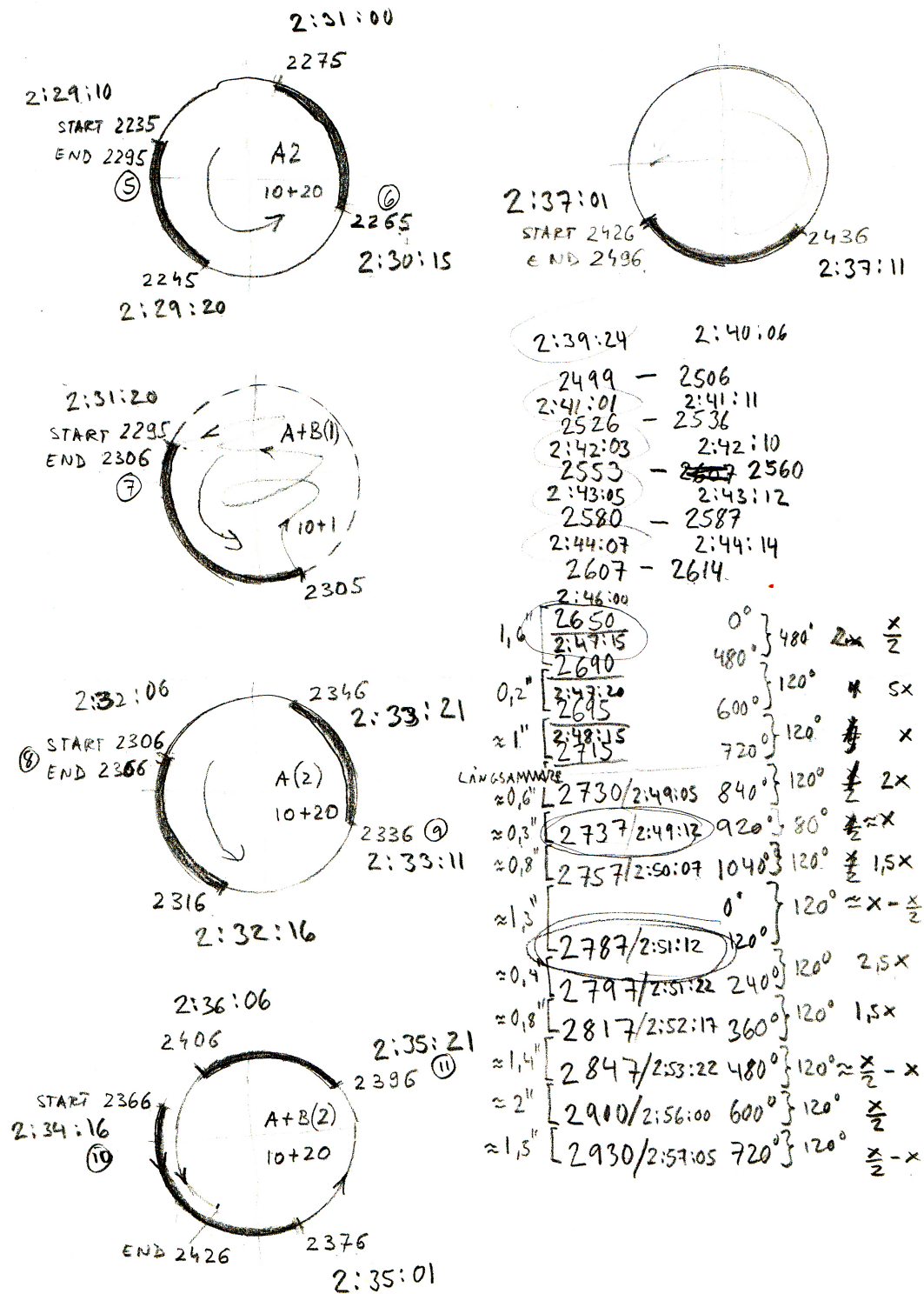


Figure 2.11. A sketch of time code used in order to illustrate the movement of the ball.

STUDSAR

	1:57:12	
1)	2937	VÄNSTER VÄGG (LÄNGST INÅN)
	2:05:18	
2)	3143	VÄNSTER VÄGG (FRÄMME)
	2:28:06	
3)	3706	BAK VÄGG (MITTEN)
	2:43:05	
4)	4080	GOLV (MITTEN, FRÄMME)
	2:51:05	
5)	4280	TAK — u —
	2:55:02	
6)	4377	TAK — u —
	3:02:05	
7)	4555	HÖRN : TAK-VÄNSTER VÄGG (MITTEN) ^{LITET FRÄMME}
	3:02:18	
8)	4568	GOLV (MITTEN, VÄNSTER)
	3:04:23	
9)	4623	HÖGER VÄGG (MITTEN)
	3:05:22	
10)	4647	VÄNSTER VÄGG — u —
	3:06:21	
11)	4671	HÖGER VÄGG — u —
	3:07:20	
12)	4695	VÄNSTER VÄGG — u —
	3:08:10	
13)	4710	HÖGER VÄGG — u —
	3:09:00	
14)	4725	VÄNSTER VÄGG — u —
	3:11:20	
15)	4870 4866	BAK VÄGG — u —
	3:14:16	
16)	4912	BAK VÄGG — u —
	3:16:12	

Figure 2.12. A sketch of time code for the computer-animated ball throwing itself against the walls, floor and ceiling. The time code was used as a time grid in Dyaxis for timing the mickey-mousing effects.

Parts of this material are present between 4'11 to 5'40 in *Reflections* and consist of gestures based on clicks and pulses, and passages that have clear accelerando, ritardando and glissando characteristics. The idea was that the music during part three would illustrate the following

At this stage it is the ball's motion that initiates the musical events, but eventually some musical strands break away and begin to lead their own lives parallel to that of the ball. Finally all correlation between the music and the ball's movements is lost.⁷⁷

⁷⁷ Extract from project description of *Inside Round*.

Part four began with the image where the ball had stopped and then continued with the ball

expanding slowly, at the same time as we are travelling into its interior, passing through thousands of images that are our mind's reflection of the outside world. Eventually it fills up the whole space and one can no longer see the room. As we travel farther and farther into the huge sphere, it disintegrates into its seed – a small dense incandescent white body shining in black space.⁷⁸

This section was also used in *Reflections* from 5'41 and onwards until the climax had ebbed away around 7'30. In *Inside Round* this was portrayed from around 8 minutes according to the overall plan in Figure 2.13 (Appendix 3).

⁷⁸ Excerpt from mail with Dinka Pignon 1995-07-04.

The camera zooms out and the rear window shows up, framing the black space with the white body. It zooms out further and we find ourselves in the room.⁷⁹

The video ended with the white body, a small white glowing circle, dissolving as the background slowly turned white. The sound portraying the end was the loud sine tone that remains and also ends *Reflections*. When listened to in loud volume, the sine tone at the end felt like it penetrated the skull and was almost physically inside our heads. We decided to use the sine tone ending in *Reflections* as we thought that it might stimulate different interpretations of what it might signify (e.g. the end of a human life). The main reason was however that we liked listening to the undulating process (beating) of two sine tones close in frequency transforming into one during the last seconds of the piece.

The collaboration process

In 1993 I experienced an accident involving exposure to a very loud sound in a studio at EMS in Stockholm whilst working on a fixed media piece. The accident damaged my hearing and I was diagnosed with “hyperacusis”⁸⁰, over sensitivity to sounds. During the period when *Inside Round* and *Reflections* were created this condition had an effect on how I felt I could work in a studio. In our collaboration we divided the sound processing tasks so that Hedman would edit and process the majority of the short and percussive sounds whereas I would work on other more non-gestural material in a different studio.

When we had created some sound material we worked together in the same studio mixing the sounds, commenting on where specific sounds should be placed in time and what new sounds were needed for the mix. Then we would work separately editing and processing sounds and meet when it was time to work with the mix again. Most sound recording was made together, taking turns on who would carry the dummyhead and DAT during the field recordings. The final stereo mix was made with the Dyaxis hard disk recording system.

⁷⁹ Excerpt from mail with Dinka Pignon 1995-07-04.

⁸⁰ Jastreboff, M., Jastreboff, P., “Hyperacusis” (Audiology On-Line June 2001), Available at: <http://www.audiologyonline.com>. Accessed 12 August 2010.

The title *Reflections* was adopted after the piece was completed. The idea with the title was to offer the listener a way of interpreting the music as the word might stimulate different associations for different people.

From stereo to multi-channel version

The multi-channel version was planned from the individual sound files in the stereo mix. First we decided what loudspeaker configuration to use. A set of thirty-one different setups was made for the 12-channel version according to Figure 2.14. The thirty-one similar setups for the 8-channel version are included in Appendix 4.

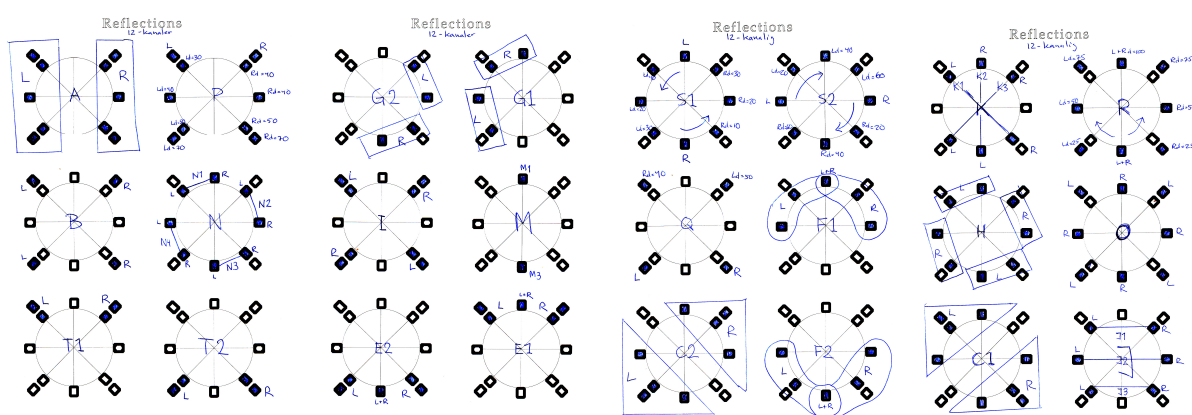


Figure 2.14. The thirty-one (J and K includes three different configurations each and N contains four) different loudspeaker configurations used for the 12-channel version.

The 12-channel version was planned with the outdoor loudspeaker sculpture in mind. The sculpture comprised eight loudspeakers at ear-level when sitting down with four loudspeakers higher up (see Figure 2.8). We wanted to enhance the directional movements for certain sounds and the four speaker configurations were constructed with these in mind (see Figure 2.15).

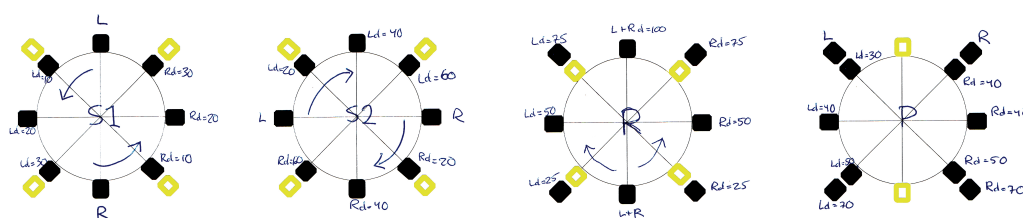


Figure 2.15. Four setups for special directional sounds.

The sounds in these configurations needed to be adjusted in volume in order to enhance movements. For example setup S1 and S2 in Figure 2.15 were used to illustrate the sound

movements that we created in stereo for the ball moving in circles in the room in *Inside Round*. Setup R was used for the sound in the beginning of part four of *Inside Round* when the ball began expanding, a sound that in *Reflections* started in the rear speaker slowly moving from the high speakers in the back towards the middle and high forward speakers until all eight speakers in the setup were used. These transitions in volume needed to be processed separately in ProTools.

We needed to decide which speaker configuration would work best for each sound so we made a work sheet for all the sounds in the mix (see Figure 2.16, Appendix 5).

The next step was to mix all the sounds into mono tracks, one track for each speaker (see Appendix 6), keeping track of volume levels and whether to use the right or the left track from the original stereo sound. For example, a sound placed in configuration G2 would have its left channel content placed in loudspeaker 5 and 6 and its right in loudspeaker 7 and 8 as seen in Figure 2.17. As there were only four loudspeakers in configuration G2 compared to setup A that contained ten, the volume needed to be adjusted up in order to keep the original balance between the sounds in the mix.

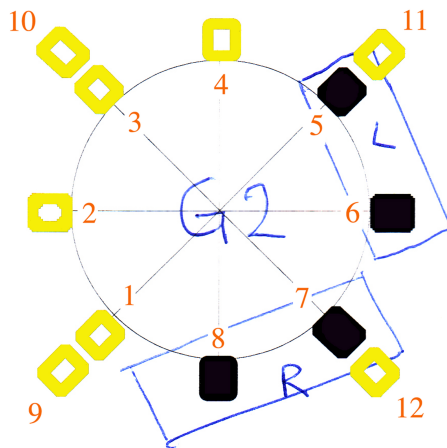


Figure 2.17. Loudspeaker configuration G2.

When all the mono tracks of the speakers were mixed we could import the material to ProTools and listen to the 8-channel mix in Studio 2 at EMS. Adjustments in level and balance forced us to create several new mono tracks for the speakers in Dyaxis until we had achieved a satisfactory result.

Evaluation

I found working together with another composer to be very stimulating and instructive. We shared our knowledge, became aware of and challenged each other's aesthetical preferences and learned from each other, creating music that none of us would have been able to compose on our own and thus creating "a collaborative musical voice". It was difficult when listening to the finished piece to distinguish who did what. The reason for this is because all of the decisions made during the compositional process were based on discussions involving both give-and-take and mutual understanding.

Using already existing material shortened the compositional process considerably as most material for *Reflections* were constructed in 1995. We could concentrate on the mixing process rather than the time-consuming task of recording, editing and processing sounds. As there were four years between the creation of *Inside Round* and *Reflections* we could listen to the sounds with fresh ears as musical material not connected to the visual media.

2.3: *Mayfly* (1999)

- fixed media: 2'20

The fixed media piece *Mayfly* was composed in 1999 for the Rien à Voir festival in Montreal, Canada, where it had its premiere in December 1999. The reason I wanted to incorporate this short stereo piece in this portfolio is because it was the first piece where I explored filtering methods to work with pitch, a method that I found fruitful and have explored ever since. *Mayfly* was also one of the first pieces where I began exploring high frequency sounds (4000 kHz and above).

Concept and method

In *Mayfly* I wanted to create a short piece based on a programmatic idea. Inspired by the piece *Flight of the Bumblebee* by Nikolai Rimsky-Korsakov (recognizable for its frantic pace when played at its proper tempo), I wanted to create a similar atmosphere with fixed media in musique concrète-style illustrating the short life of a mayfly.

The earlier collaboration piece *Reflections* was to a certain degree based on a programmatic idea and I wanted to explore this concept again, this time making a short piece. Would a programmatic idea be a constructive way of structuring the material in a composition? Would the non-musical idea be audible or perceived in the music?

I wanted to use material with clearly audible pitch, and the pitched sounds would be based on musique concrète sound sources, not created with synthesis techniques. In *Mayfly* I wanted to create a forward-moving and lively character. This because I felt that the two previous pieces works had mostly been based on slow timbral transformations.

Compositional process

Mayfly was composed in a very intuitive manner. Sounds were created in order to work with the programmatic idea and the structure of material in time was allowed to change as the piece progressed. A four minute long mix was composed and the material was reduced, again more material composed (in order to work with the new form) and reduced again, a process that continued until I was satisfied with the result (see Figure 2.18).

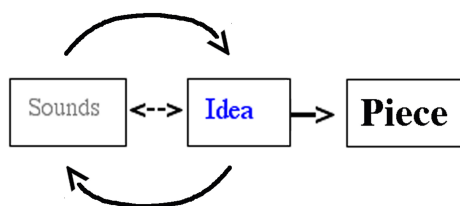


Figure 2.18. A simplified model of the compositional process of *Mayfly*.

The programmatic idea and its effect on the sound material

Instead of runs of chromatic sixteenth notes as in *Flight of the Bumblebee* I used a shuffling tool and granulation in order to create a quick pulse to symbolise the flight of the mayfly.

The sound material consisted mostly of recordings of stone marbles, paper, cardboard boxes and terracotta pots. These sounds were edited and processed in software programs like Sound Designer, Peak, GRM-tools and Soundhack. A Lexicon reverb was also used as a processing tool. Most of the sounds were heavily processed, as I wanted to avoid references to the origin of the sounds. I wanted to create a sonic environment that would help the listeners' *reduced listening*⁸¹.

The overall form of the piece consisted of several sonic spaces that were joined together with a main theme, an iterative sound, and reoccurring sounds such as the pitch-filtered terracotta object. At least two sonic layers were present at all times, sometimes more, and the majority of the processed sounds used were granulated, pitch-filtered and rapidly repeated (iterated) high frequency sounds in contrast to a low bass register. The visual representation of *Mayfly* as a sonogram (see Figure 2.19) shows strong activity in high frequency register.

⁸¹ 'écoute réduite' – *reduced listening* – the listening intention as described by Pierre Schaeffer in Schaeffer, P., *Traité des objets musicaux*, Ed. du Seuil, (1966).

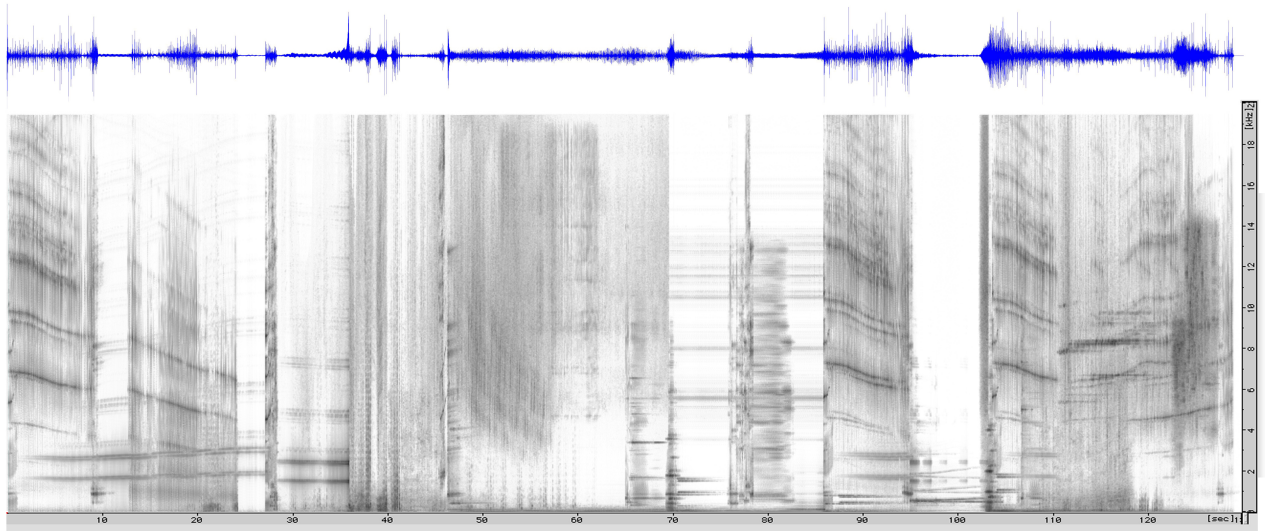


Figure 2.19. A sonogram and amplitude (in blue colour) representation of the whole piece. The x-axis: seconds, the y-axis: frequency in Hertz.

The sonogram in Figure 2.20 shows two layers in the beginning of the piece; an iterated high in frequency sound without a clear pitch moving downwards as glissando and another iterated high frequency sound with more audible pitch.

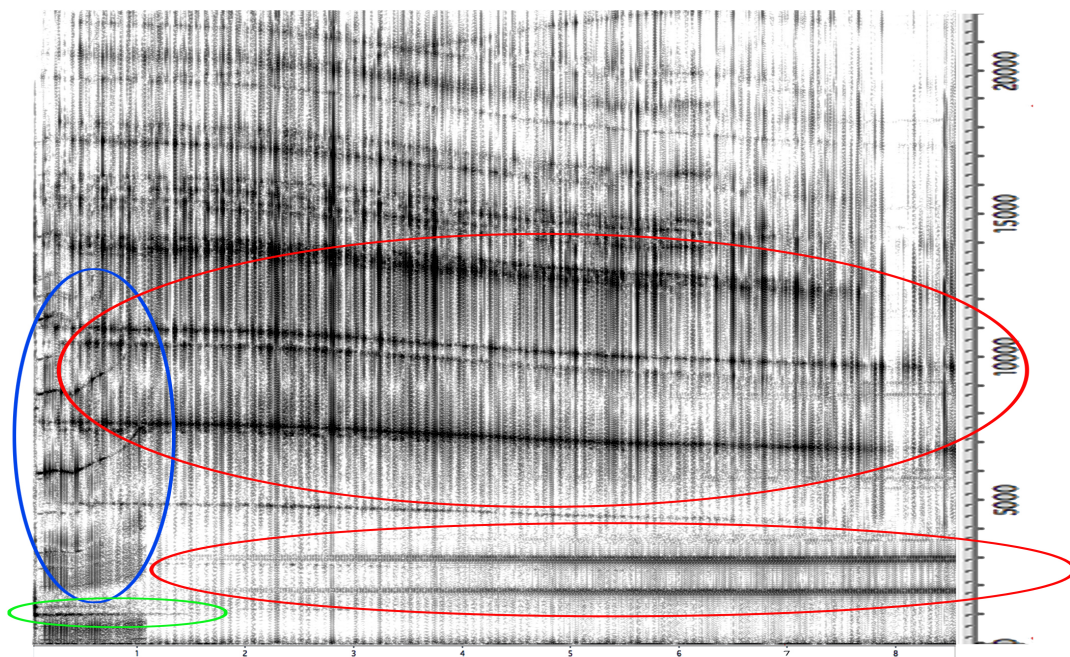


Figure 2.20. A sonogram representation of the first eight seconds of *Mayfly*. The x-axis: seconds, the y-axis: frequency in Hertz. The striped sonogram shows that the sounds are iterated. The high-pitched sound is seen in the lower red circle and the glissando sound in the upper. The blue circle represents pitch-filtered terracotta sounds and the green circle a processed stone marble sound. Most material for the whole piece was derived from these four sound sources, paper and sounds from cardboard boxes.

Pitch material

As opposed to the earlier piece *Ti Chor*, the use of pitch in *Mayfly* was mostly intuitive. I listened to the recorded material and chose one sound with a clear audible pitch. Other sounds were then transposed or filtered in relation to this chosen sound. There was no overall development of pitch in time; all decisions were based on listening repeatedly to the material. Careful consideration was taken to give specific sounds an audible pitch and it was in this piece I started to consciously use filtering as a method of achieving this.

Evaluation

In *Mayfly* I wanted to explore if a non-musical idea could be a constructive way of structuring the material in a composition. The idea of trying to illustrate something other than music i.e. illustrating the short life of a mayfly, felt musically uninteresting and unsatisfying to me. My conclusion was that I needed to explore ways of structuring the material in a composition further using other kinds of non-musical ideas. This conclusion turned out to be the basis for all future compositions with one exception, *Clandestine Parts*.

In *Mayfly* I composed with gestures at high frequencies, around 4000 Hertz and above. This was a new experience and something I wanted to develop further in my next piece as I experienced a strong sense of directional movement in these high frequency areas.

2.4: *Clandestine Parts* (2000)

- fixed media in stereo and 8-channel: 8'09 and 10'09

The fixed media piece *Clandestine Parts* was composed in 2000 and exists in two versions: An eight minute stereo version for the Electron Records CD *Currents*⁸² and a longer ten minute 8-channel version, specially commissioned by the Swedish National Concert Institute (Rikskonserter) for the open-air pavilion Elektrofonen. When *Clandestine Parts* is mentioned in the text below it will be to the longer 8-channel version that I refer.

⁸² Released in 2000 on the record company Elektron Records run by the organisation SEAMS (Society for Electro-Acoustic Music in Sweden), Elektron EM 1002.

Concept and method

The main concept for *Clandestine Parts* was to explore very high frequency sounds in the region of 4000 Hertz and above. I wanted to explore directional movements in space and timbre within this register.

The method I used was filtering sounds so that they would have their own unique character, a technique that will be explained in detail below. Two versions of the piece were made in order to compare the difference in directional movements using the same material: first a stereo mix for headphones and then an 8-channel version for loudspeakers.

Another concept was to compose a piece that would have a more complex form than a more traditional arched form. In order to do this I experimented with different concepts of how to structure material in time. A programmatic idea such as constructing an overall form based on the idea of growth (a seed that expands to a tree) was explored and later rejected. I also explored the concept of constructing a non-musical grid based on analysed events from a recording as will be discussed in detail below, a time-grid that would structure the material in the piece regarding frequency register and placements of gestures.

Compositional process

As with *Mayfly* there was originally a programmatic idea behind the piece. This time the inspiration for the idea came from listening to a short percussive sound. An overall form based on the programmatic idea of the seed growing and becoming a full-grown tree was then constructed. However, once I started editing the material, the original programmatic idea was abandoned in favour of another programmatic idea based on new sound materials (see Figure 2.21), the sounds of a time-stretched wine glass and of bells. The new idea was to portray a dream-like atmosphere using the pitch content of the bell sound as a starting point for the harmonic content throughout the piece.

Clandestine Parts is inspired by the dreams I remember from my childhood. At times, sleep was haunted by vivid nightmares, full of fear and technicolour dread. But ever so often, like a soft whisper drowning out the noise of chanting mob, I was relieved by a purely joyful dream with a happy ending.⁸³

⁸³ Programme note from *Clandestine Parts*.

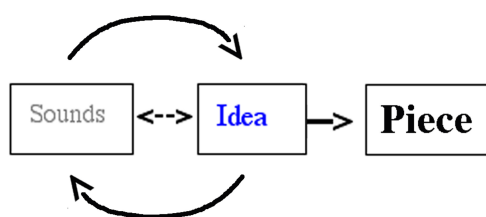


Figure 2.21. A simplified model of the compositional process of *Clandestine Parts*.

The results of the time-grid

In the early stages of the compositional process I searched for ways to construct a time-grid for the whole piece. The idea was to free myself from my subconscious musical mind in order to explore form as many of my previous pieces tended to have an arched form. One method I explored in order to construct the time-grid was to analyse a section from a few minutes of a martial arts session⁸⁴ that I had recorded with lots of people, both children and adults, shouting as they executed movements in their own pace (Sound example 1). I chose 16 seconds from the recorded material, listened and wrote down a rhythm and pitch-grid based on these shouts. The pitch-grid was divided into several groups such as high, middle and low and the rhythm-grid was stretched in time to give a total length of eight minutes.

The use of these grids to structure the material throughout the piece was however not followed through as I felt that the sound material I developed later suggested a more intuitive path. What remained from the experiment with the martial arts grid may be heard at 6'02 in *Clandestine Parts* (see Figure 2.22) on top of the sustained sound with the pitch C (beginning at 5'58).

⁸⁴ The martial art session was recorded with permission from the World Koong Joong Hapkido Association based in Norwich, UK.

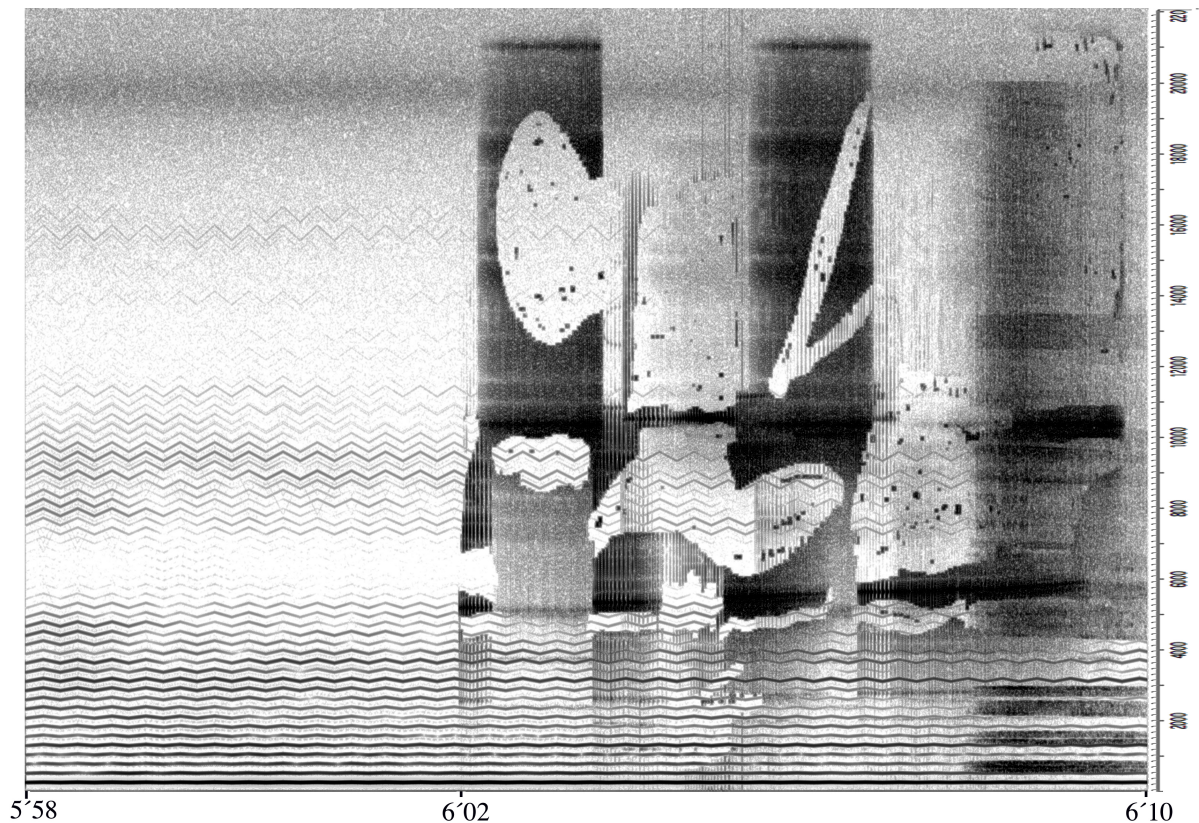


Figure 2.22. A sonogram of the section between 5'58 and 6'10 in *Clandestine Parts*. The y-axis: frequency in Hertz.

The sound material and filtering process

The sound material consists mostly of recorded musique concrète sounds processed in software programs like ProTools, Audiosculpt, GRM-tools, Turbosynth, Supercollider, Soundhack and Metasynth. The musique concrète sounds were recordings of egg boxes, wine glasses, clocks, metal plates, stone marbles, voices and short percussive sounds.

Also a preset sound from Metasynth was used, a musical greeting to those composers who used Metasynth at the time. This preset sound was used as a motif in various processed forms throughout the piece and is heard for the first time at 3'55 – 4'01. Also FM and additive synthesis techniques were used.

The section described in Figure 2.22 was based on a short sound from winding a clock that I edited and processed (Sound example 2) in order to fit with the original 16 seconds long time and pitch grid. The sound of the original recording (slightly filtered) may be heard together with the processed sound in Sound example 3. The winding clock sound was processed so

that it would contain strong partials in the high frequency register and filtered so that each repetition of the sound would have a different character as seen in Figure 2.23.

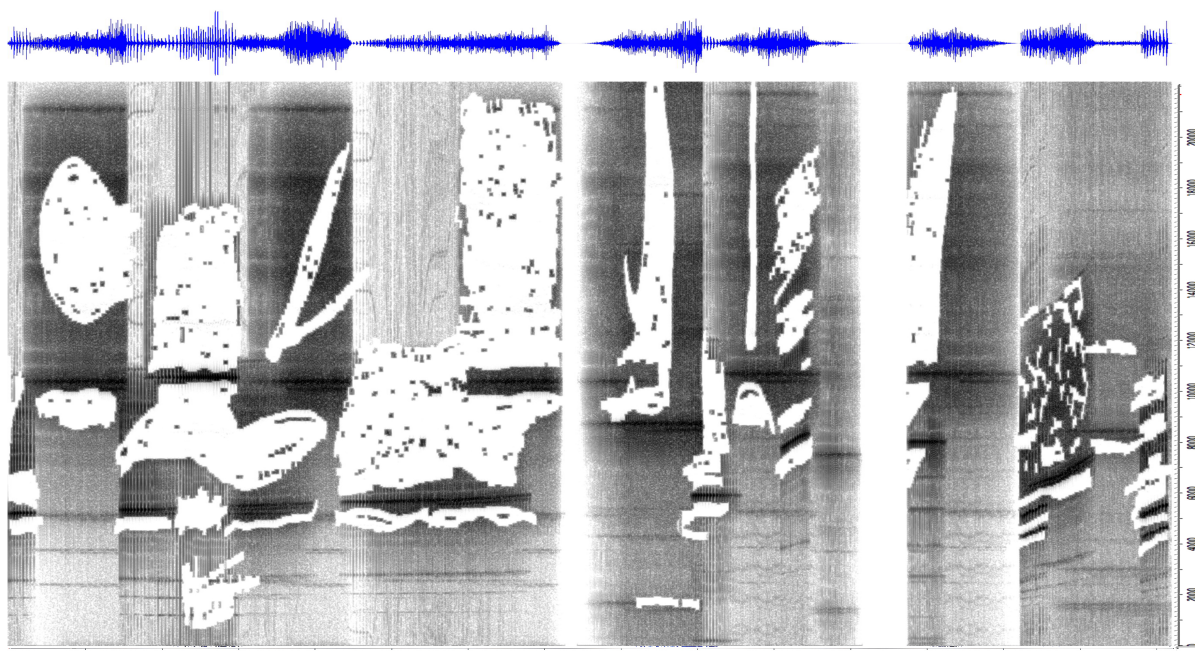


Figure 2.23. A sonogram and amplitude (in blue colour) representation of the processed sounds in Sound example 2 that were based on the martial arts grid. All sounds were filtered differently as can be seen with the white areas in the sonogram. The x-axis: time in seconds, the y-axis: frequency in Hertz.

In order to distinguish between the different layers of high-pitched noise used in *Clandestine Parts I* I used a lot of filtering techniques with software programs such as Audiosculpt and Metasynth. Also the Q10 plug-in in ProTools was frequently used to filter out specific pitches from the noise as with the sound marked in green circles in Figure 2.24.

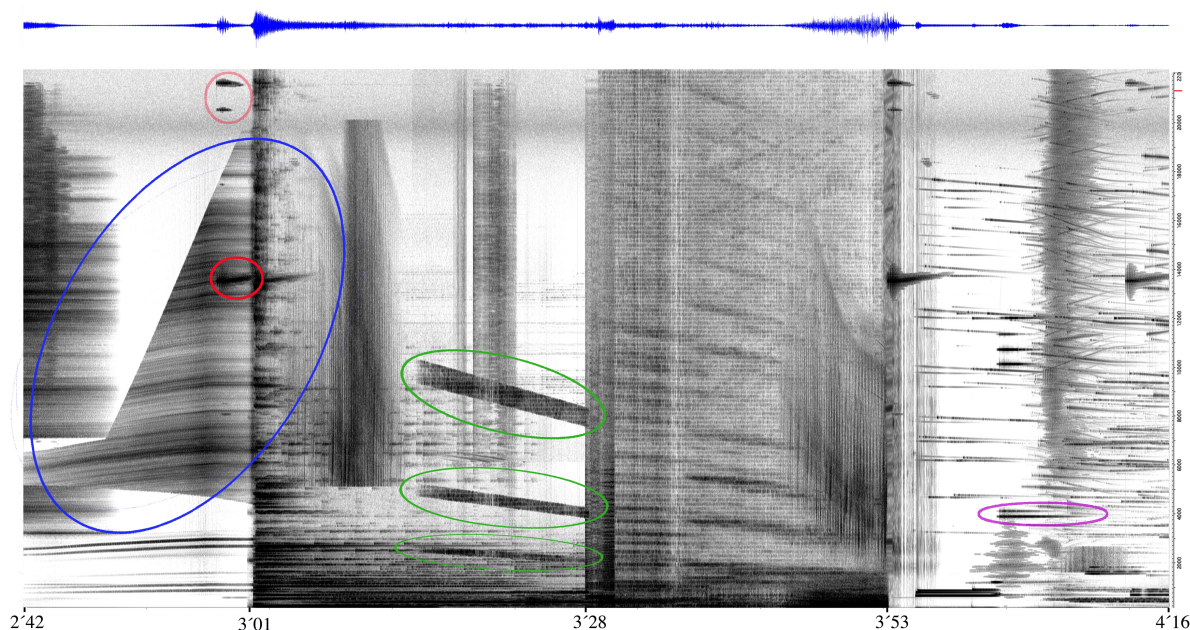


Figure 2.24. A sonogram and amplitude representation of the sound events between 2'42 and 4'16 in *Clandestine Parts*.

One technique used to create high pitched sounds was to filter a specific pitch in a low register (for instance a harmonic spectrum with a fundamental pitch of 220 Hz) and then transpose the sound many octaves and then filter the sound again (this time focusing only on the new fundamental i.e. 7070 Hz). An example of a sound (originally a bell sound) created with a similar process is marked with a red circle in Figure 2.24.

In Figure 2.24 an example of a sound created with FM synthesis techniques is marked in violet, a technique that proved to be useful making pitches in high frequency register.

The construction of the piece

Throughout the piece there were certain sounds that determined the pitch content of others. All the material in the beginning of the piece and the sound material from 2 minutes (see the blue circle in Figure 2.24) leading up to the attack at 3'02 were filtered to fit the formant spectrum of the bell sound in the attack. Filtering different partials from the bell sound onto the sound material created a sense of directional movement as the sound material changed slowly from one prominent partial to another, a kind of “spectrum glissando” as can be heard in 2'42-2'58 (see ‘a’ in Figure 2.25). The filtered material was originally a time-stretched wine glass sound (a few seconds long sound that ended up as a thirty-seven minutes long time-stretched sound with the help of the software program Soundhack), a sound that occurs in various processed shapes throughout the piece.

The most prominent partials of the bell sound that I chose to work with were found at C, D, D#, E, F#, A and B. Especially the intervals E to D and B to A were easily audible to the ear as a theme and I chose this pitch material as starting point for the harmonic development in the piece. I chose also to work with some of the intervals derived from the material - seconds, fourths and fifths.

The cicada sounds in the beginning of the multichannel version were filtered so that the pitch E would be perceivable, thus establishing a tonal centre before the wine glass sounds filtered with E and A (see ‘b’ in Figure 2.25) were introduced at 2'00.

Short sounds from the martial arts material in part five were processed with time-stretch and filtering. These may be heard as the high frequency gestures at 2'32-2'42 (See 'c' in Figure 2.25).

A high filtered sound (the sound marked with a red circle in Figure 2.24), was used as a contrast to the mellow filtered noise sounds – to give sharpness to the sonic image and to herald the sounds of the bell-sounds in the attack at 3'02 and the Metasynth sounds that appears at 3'55 for the first time (see 'd' in Figure 2.27).

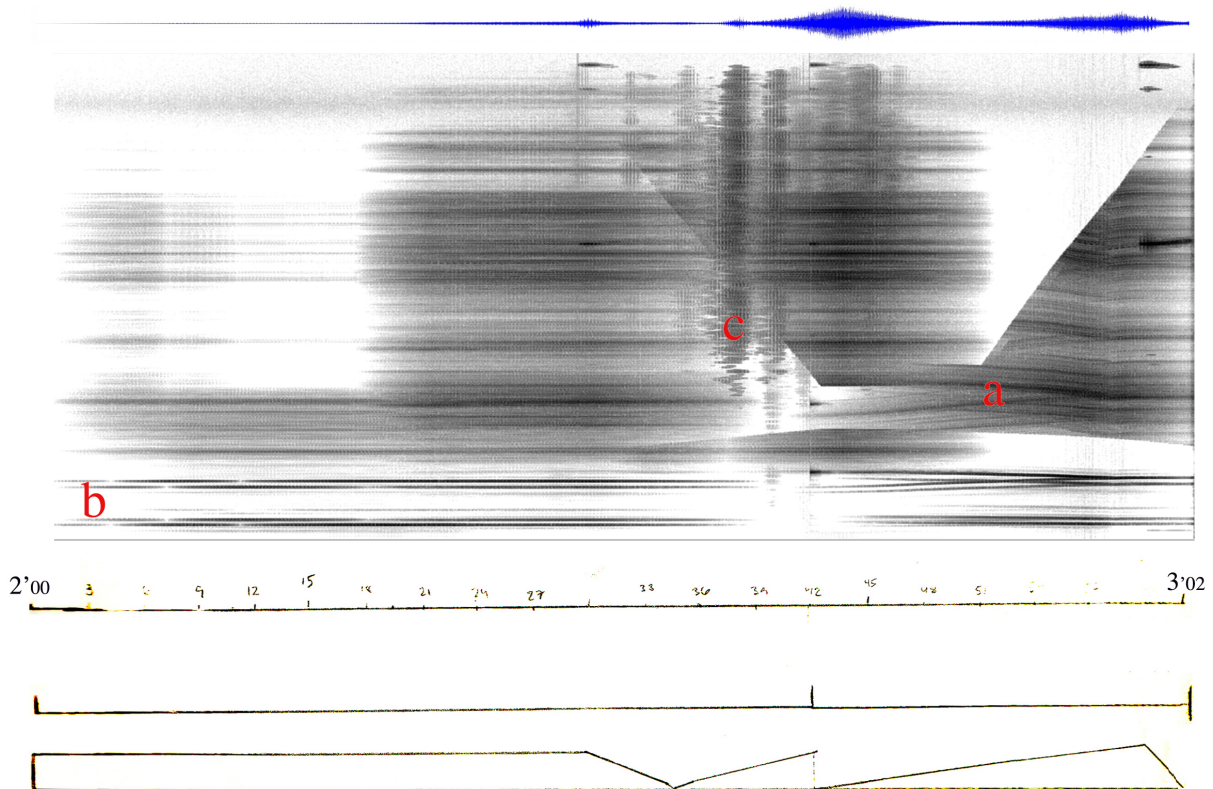


Figure 2.25. Section 2 at 2'00-3'02.

The attack at 3'02 in the third section consisted mostly of sounds from the bell and octave transpositions of it (see 'e' in Figure 2.26). These sounds were filtered differently and processed in the ProTools plug-in S2 giving each sound a specific placement in the stereo image.

In this section the bell-sounds were accompanied by lots of high frequency noise based sounds and at the end of the section these filtered noise sounds had transformed from very high pitch to low pitch through layers of gestural material with a perceived glissando effect (see 'f' in Figure 2.26). Most of the noise sounds were made of grain synthesis in

SuperCollider and then filtered to specific frequency bands in Audiosculpt. Some of these sounds used in the glissando effect were processed with the time-varying speed function in Soundhack (see ‘g’ in Figure 2.26).

Materials based on the human voice were also used, sounds that were high pass-filtered and mixed in many different layers and may be heard at 3’32-3’37 with an A pitch in octaves (see ‘h’ and ‘i’ in Figure 2.26). Again sounds from the martial arts material were used but heavily processed (see ‘j’ in Figure 2.26).

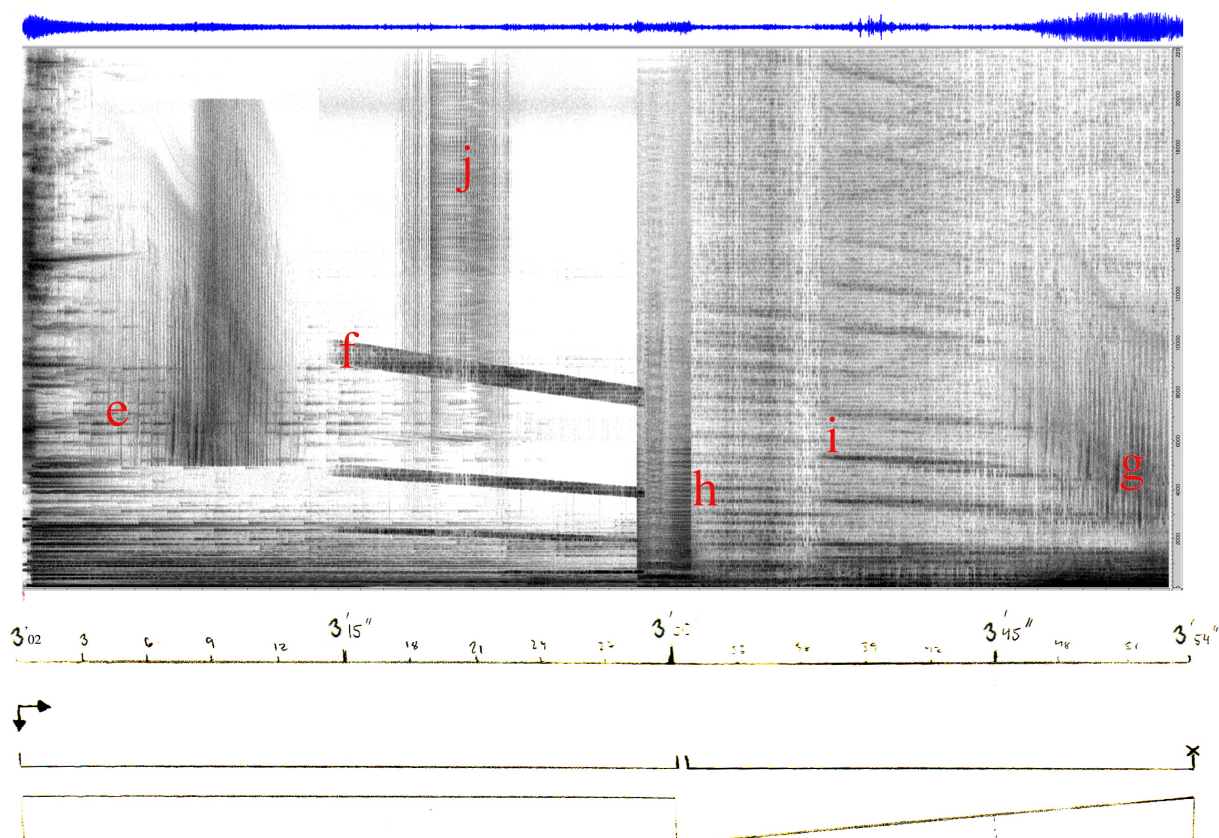


Figure 2.26. *Clandestine Parts 3’02-3’54.*

Section four begins with a transition from a high frequency shuffled sound gesture (see ‘k’ in Figure 2.27) to the Metasynth motif (see ‘d’ in Figure 2.27) containing the pitches F to F#, here presented for the first time together with FM sounds made in SuperCollider (see ‘l’ in Figure 2.27). The motif, recognizable for its minor second interval, then occurs throughout the sections in processed shapes with different depths in the sound image and different transpositions such as heard in 4’14-4’22. A high frequency gesture based on the pitch E is introduced at 4’32-4’52 (see ‘m’ in Figure 2.27).

Gestures mostly based on previous material then conclude the fourth section.

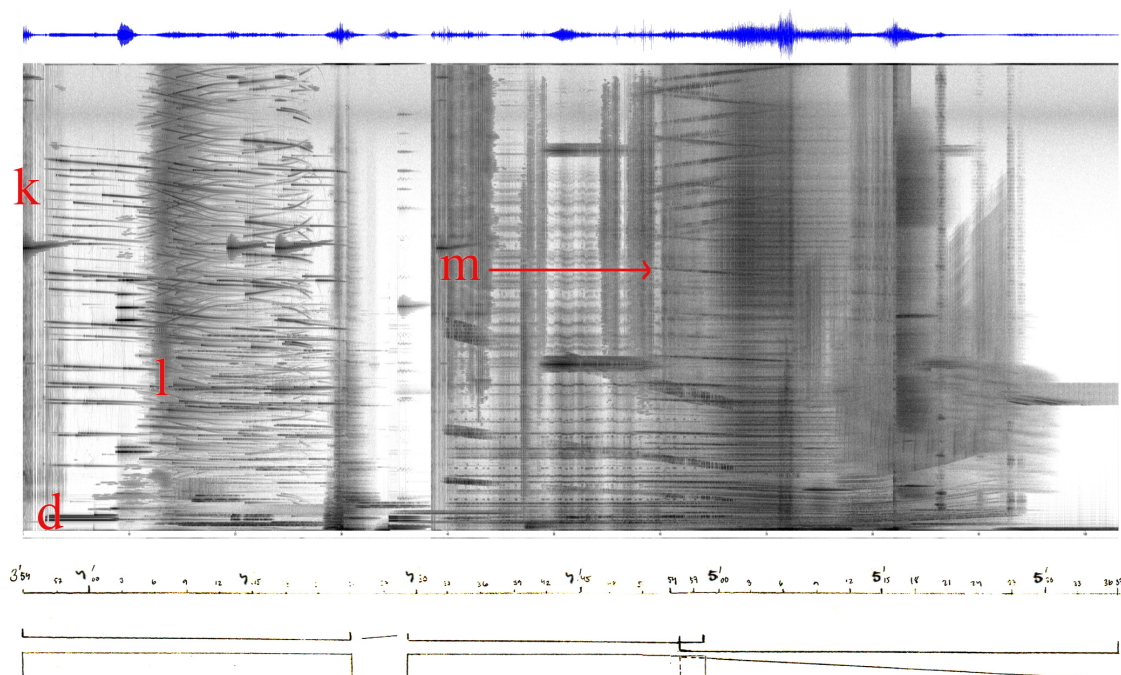


Figure 2.27. *Clandestine Parts 3'54-5'37.*

Section five is a short interlude between 5'37-5'59 portraying a transition to programmatic “deeper sleep” with a quiet low frequency gesture appearing three times with silence in between (see ‘n’ in Figure 2.28).

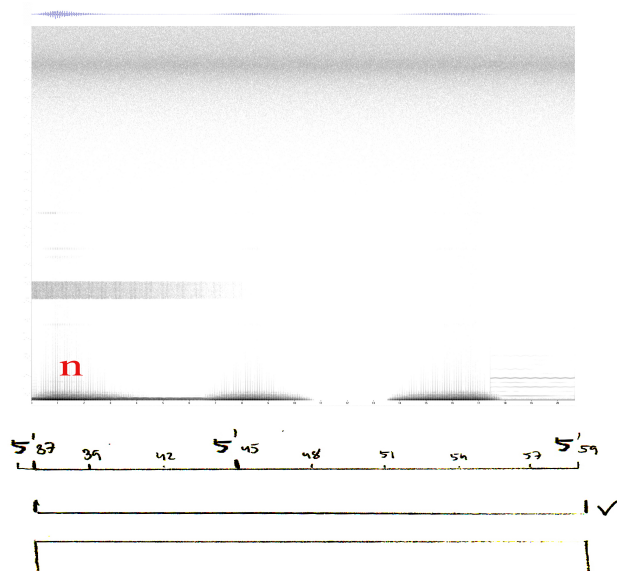


Figure 2.28. *Clandestine Parts 5'37-5'59.*

The sixth section begins at 5'59 with a sound containing a harmonic spectrum based on C made with synthesis in Turbosynth (see Figure 2.29 and ‘o’ in Figure 2.30). I applied partials from this sound as a frequency grid when I filtered other sounds during the second half of the

piece. For example, the noise sounds at 6'15 were filtered in Audiosculpt to be within a certain range as seen in Figure 2.29.

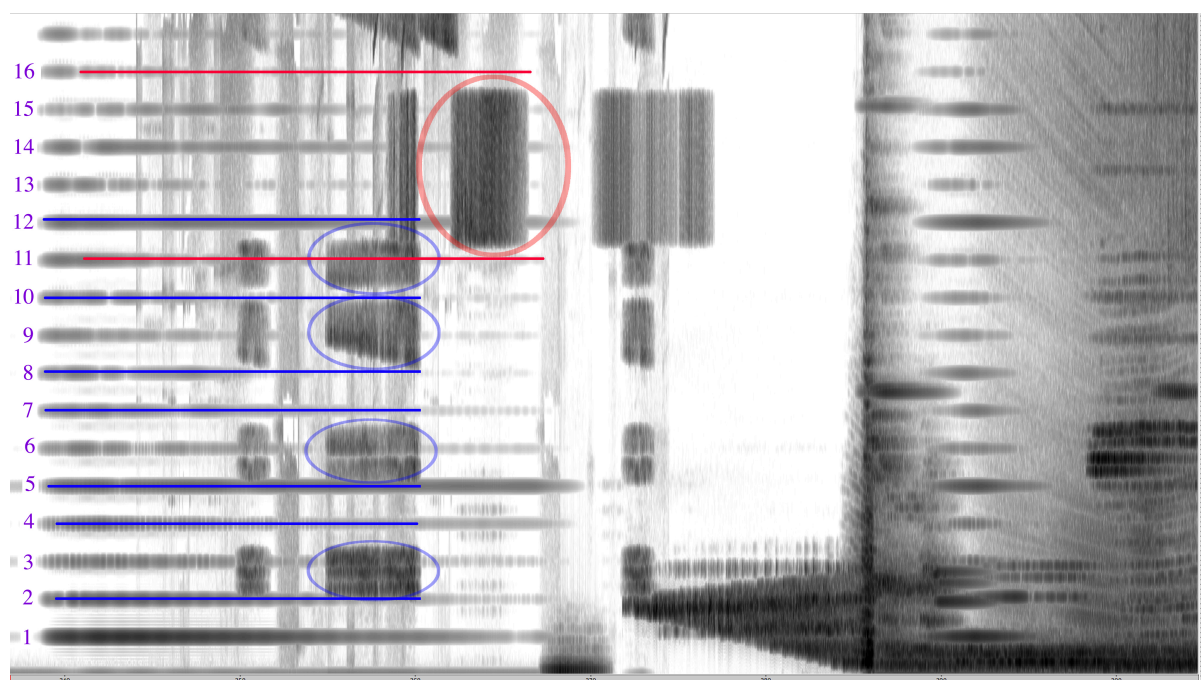


Figure 2.29. Example of filtering technique used in *Clandestine Parts*.

The pitch filtered noise sound at 6'15 marked in blue had a frequency grid between partial no. 2-4, 5-7, 8-10 and 10-12 of the synthesised sound. The sound at 6'22-6'25 marked in red had a larger grid, between partial 11 and 16. This was one of several filtering techniques used throughout the last sections of the piece. Another technique was to filter the formant spectrum of the Turbosynth sound onto other sounds, creating a tonal atmosphere.

Processed sound material from the previous parts were used in section six along with other material such as high frequency terracotta sounds, establishing a kind of tonal centre from which the material shifts at 8'00 returning to the bell-spectrum again. Figure 2.30 shows the occurrence of the Turbosynth sound ('o') and the Metasynth motif ('d').

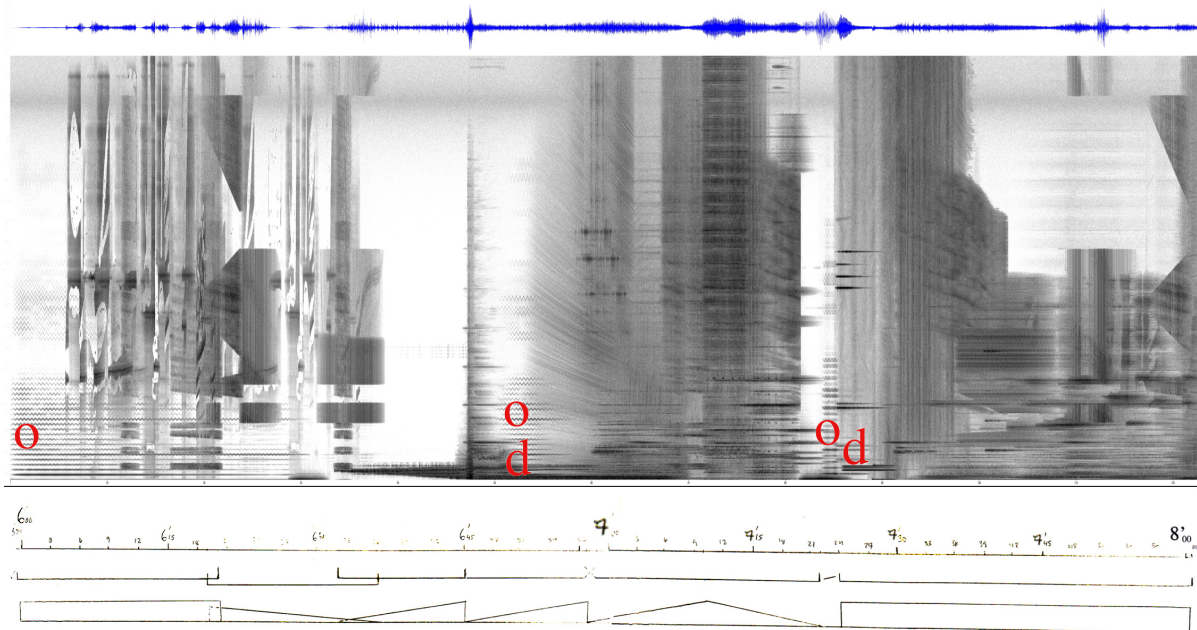


Figure 2.30. *Clandestine Parts 5'59-8'01.*

In the last section the material consists of sounds based on the bell-spectrum from section one, two and three (see 'p' in Figure 2.31) and also sounds based on the harmonic spectrum introduced in section six (see 'q' in Figure 2.31) establish an underlying tonal centre on B and F#. A bell-sound made with FM at 9'15-9'24 modulates the tonal centre to C and G at 9'24. The piece ends with the sound of the filtered time-stretched wine glass with pitches A and D (see 'r' in Figure 2.31) accompanied by pitched noise sounds (see 's' in Figure 2.32).

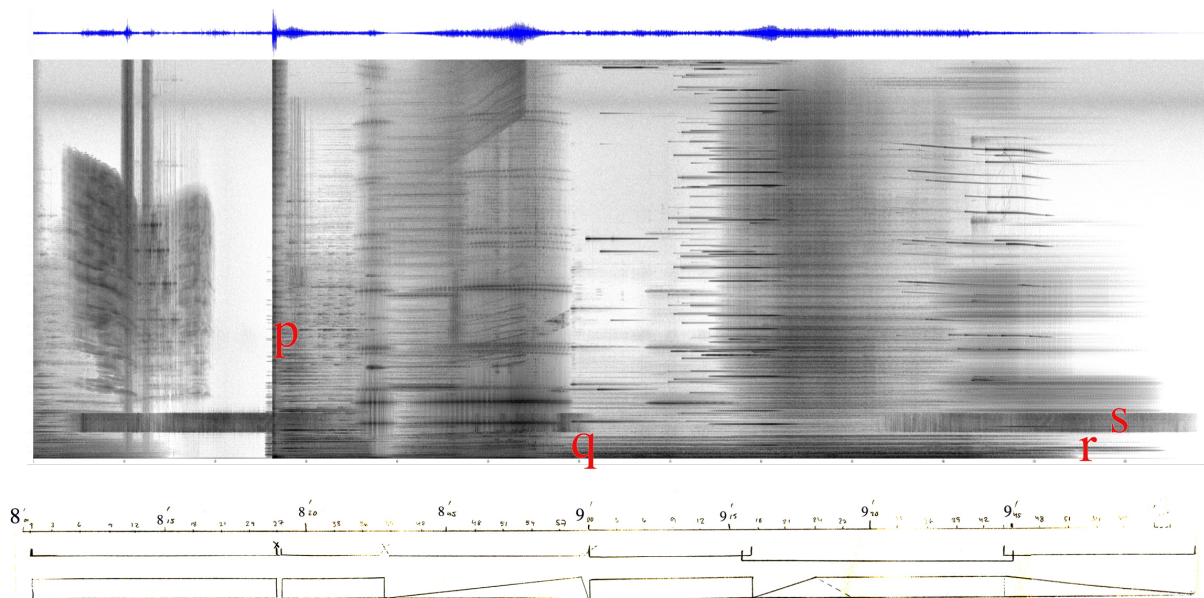


Figure 2.31. *Clandestine Parts 8'01-10'09.*

The piece begins with a tonal centre of E and ends with the interval D and A, pitch material derived from the bell sound in 3'02. The harmonic structure was not planned out in detail in advance and was mostly based upon intuitive decisions during the compositional process.

From stereo to multichannel

The stereo version of the piece was mixed in ProTools using headphones. The multi-channel version was planned from the stereo mix in the same manner as was done in *Reflections*. Each separate stereo soundfile was given a placement in a speaker configuration according to Figure 2.32.

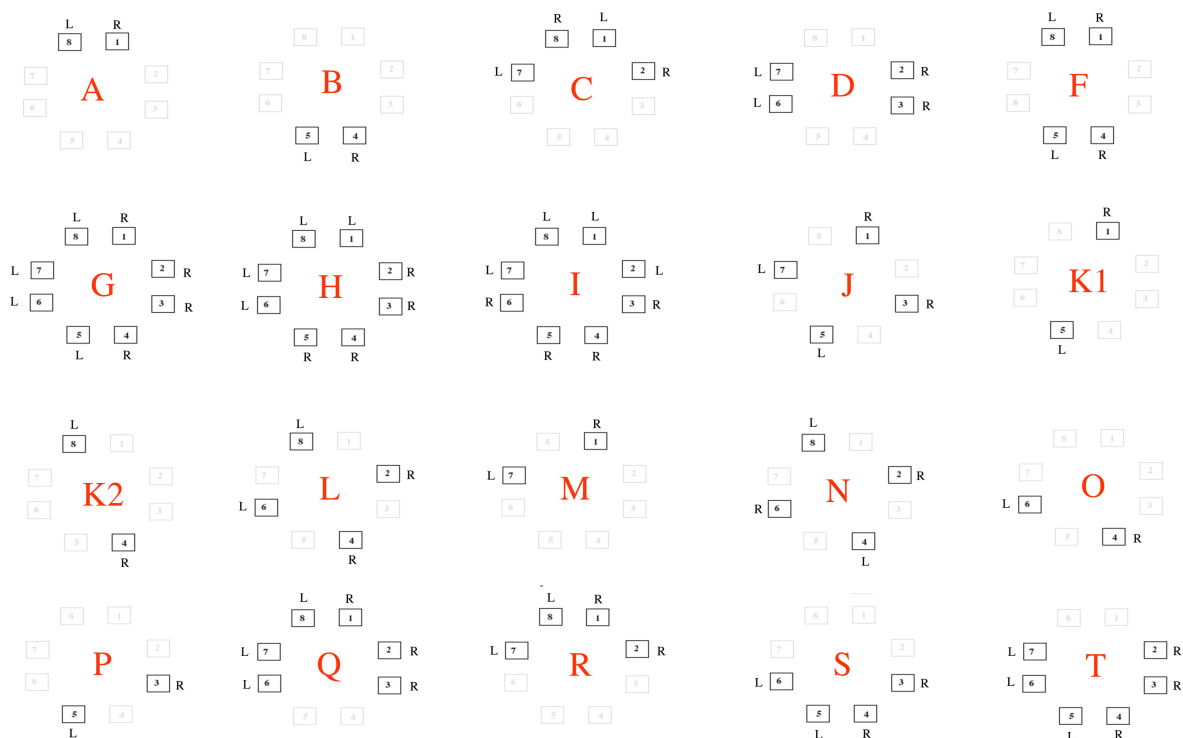


Figure 2.32. Twenty different loudspeaker configurations.

For example: If sound no. 1 was placed in speaker setting A, I mixed the right mono track of the sound file in speaker 1 and the left in speaker 8. If sound no. 2 was placed in speaker setting L, I mixed the right mono track of the sound file in speaker 2 and 4 and the left in speaker 6 and 8. When all the sound files had been placed in a loudspeaker configuration I mixed a mono track for each of the eight speakers.

As some of the speaker configurations contained all eight loudspeakers and some only contained two, I needed to compensate the volume in each speaker setting (see Figure 2.33).

Högtalare 1:			Högtalare 3:			Högtalare 5:			Högtalare 7:		
Left	Right		Left	Right		Left	Right		Left	Right	
C	A	+6		D	+3	B		+6	C		+3
	F	+3	G			F		+3	D		+3
	G			H		G			G		
H				I			H		H		
I				J	+3		I		I		
	J	+3				J		+3	J		+3
	K1	+6		P	+6	K1		+6	M		+6
	M	+6		Q	+1,5	P		+6	Q		+1,5
	Q	+1,5		S	+3	S		+3	R		+3
	R	+3		T	+1,5	T		+1,5	T		+1,5

Högtalare 2:			Högtalare 4:			Högtalare 6:			Högtalare 8:		
Left	Right		Left	Right		Left	Right		Left	Right	
	C	+3		B	+6	D		+3	A		+6
	D	+3		F	+3	G			C		+3
	G			G		H			F		+3
	H			H			I		G		
I				I		L		+3	H		
	L	+3		K2	+6	O		+6	I		
	N	+6		L	+3	Q		+1,5	K2		+6
	Q	+1,5		O	+6	S		+3	L		+3
	R	+3		S	+3	T		+1,5	N		+6
	T	+1,5		T	+1,5				Q		+1,5
									R		+3

Figure 2.33. List of volume compensation in dB for each setting and loudspeaker (Högtalare).

When all eight mono tracks were mixed I listened to the mix in an eight-channel studio and made corrections and adjustments in order to get the balance right.

The title

Clandestine Parts was given its title after the piece was finished. The fact that the piece contains a lot of sounds in such a high frequency register that some people will not be able to hear them at all, made me think of the title. I experienced this myself as one of my eardrums burst just after the final mixing of the piece. During a period of four weeks I only perceived a fraction of what I had heard before when I composed the piece. Listening to the mix when my ear was damaged made me think of how much sound material that during this period was hidden from me, sound material that I remembered and knew was there but could not hear.

Evaluation

I found working with high frequency sounds very satisfying even though sometimes hard on the ears. My conclusion regarding directional spacing with the different high-pitched sound layers was that it worked well in both headphone stereo and multi-channel version. In a

concert situation however, the multi-channel version was superior, something that seems to be supported in research concerning sound perception and localization.⁸⁵

Even though I did not use the overall form based on the original programmatic idea and did not use the various different ways of shaping the overall form of the piece that I explored, I was content with how the overall form turned out in the end for the eight minute long stereo version. When the piece was finished I made a time field analysis based on Lasse Thoresen's method⁸⁶. I wanted to see how the intuitive choices I made for the timing of events effected the form of the piece – would the result be yet another arched form? The analysis however showed that the overall form for the stereo version was not arched (see Figure 2.34 and Appendix 7).

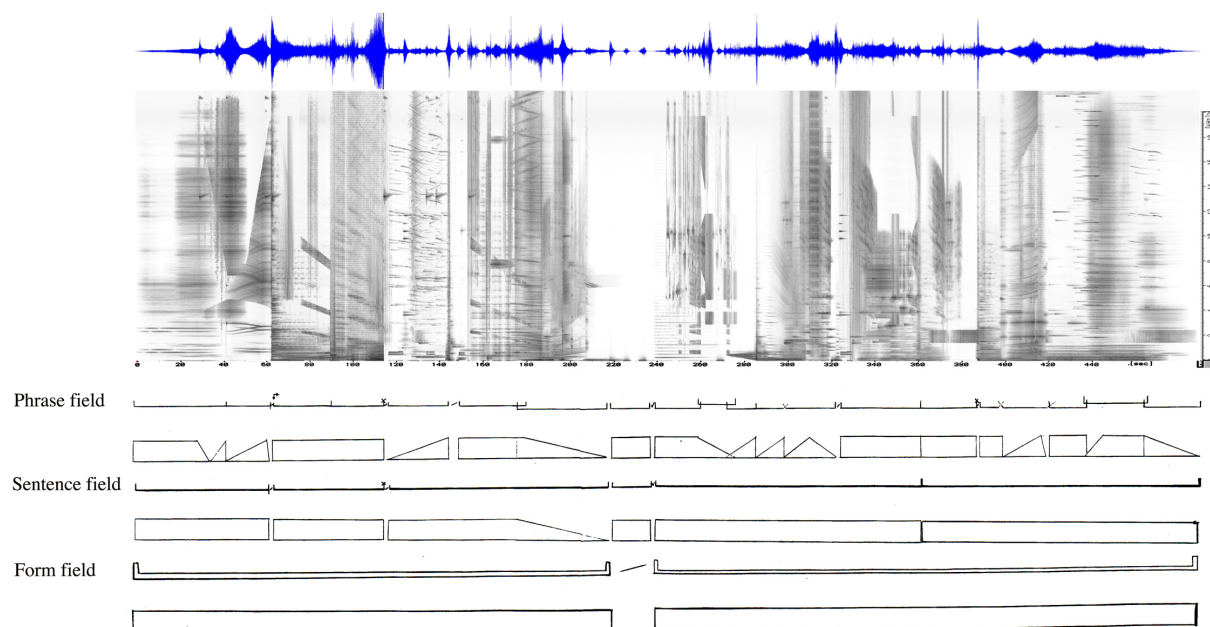


Figure 2.34. A time field analysis with time directions based on the eight minute long stereo version of *Clandestine Parts*.

The concept of using information as a grid to structure material in pitch and time appealed to me and after exploring the martial arts grid I wanted to explore this idea further in the next piece in my portfolio, *Med lekande kval*.

⁸⁵ Dowling, W. J. and Harwood, D. L., *Music Cognition*, Academic Press, (1986), pp. 56-60.

⁸⁶ Thoresen, L., "Auditive Analysis of Musical Structures. A summary of analytical terms, graphical signs and definitions." *Proceedings from ICEM Conference on Electroacoustic Music Stockholm, Sweden, 25 –27 September 1985*, Editor: Bo Rydberg, (1988), pp. 65-90.

2.5 *Med lekande kval* (2001)

- fixed media in stereo and 5-channel: 3'10

The title *Med lekande kval* (*With Playful Toil*) was derived from the text of the song *Liksom en herdinna högtidsklädd*⁸⁷ (*Like a shepherdess in her finery*) written by the Swedish 18th Century poet Carl Michael Bellman. The song by Bellman was used as a means to structure material in *Med lekande kval* as will be discussed below. The piece was composed in 2001 and had its first performance at the Elsvets festival at Fylkingen in Sweden the same year.

Concept and method

The concept behind *Med lekande kval* was to investigate how an existing musical form could be used to structure the harmonic content and progression in time. How would the compositional process be affected and what effect would the imported harmony have on the end result, the final composition?

In *Med lekande kval* a ready-made harmonic structure based on the 18th century folk song was used as a foundation. This structure was used to determine not only the harmonic progression within the piece but also the duration of the whole work as well as the subdivisions throughout it.

An analysis of the harmonic structure in the Bellman piece was made based on the score in Figure 2.36. Also the melody was used in the compositional process as will be discussed below. The sound material was chosen and edited in such a manner that it would fit in with the traditional harmonic structure, no matter its original spectral content.

Compositional process

In *Med lekande kval* the imported musical form (M), the Bellman-piece, was used to structure both the harmonic content (H) as well as how harmony progressed in time (see Figure 2.35). The imported form was also used to determine when certain gestural events were to take place

⁸⁷ Also known as *Fredmans epistel Nr. 80*.

within the piece (T). However, that time-grid was slightly modified throughout the compositional process.

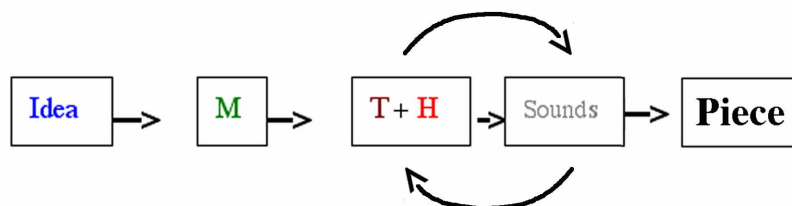


Figure 2.35. A simplified model of the compositional process of *Med lekande kval*. The imported musical form (M) controlled the time domain (T) as well as the harmony content (H) and its progression in time. The sound material was allowed to modify the time-grid and the harmonic content.

The compositional process was flexible to a certain extent and the time-grid was slightly modified when the sound material suggested that a change should be made. Also the harmonic progression was occasionally altered whenever the sound material during the compositional process suggested a different harmonic development. New chords were introduced in order to avoid a feeling of predictability when the imported harmony was perceived static and “not leading anywhere” but I tried to maintain harmonic patterns similar to that of the original piece.

The Musical structure

The harmony in the song *Liksom en herdinna högtidsklädd* is that of traditional song harmony with tonic, subdominant and dominant relationships. A minor and major tonality with diminished chords and dominant sevenths present.

The key is A minor and the song is in two parts where the first part is repeated twice before continuing to the second part as seen in Figure 2.36. As the end of *Med lekande kval* was composed first, I decided that the piece would finish on the E7 chord, the last chord found in the fourth bar from the end in the Bellman piece (see red circle in Figure 2.36). The remaining text from there on to the end in the first verse is “[Hon] flätar med lekande kval” ([she] twines with playful toil), hence the title for the new piece. The end was composed first so that during the compositional process I would not be tempted to allow the sound material suggest a direction other than the original idea for the piece, something that did occur when I worked with *Clandestine Parts*. If the end already was finished I could relate the beginning to the end instead of the other way round, for me a new compositional process.

„Låksom en herdinna högtidsklädd.”

C. M. Bellman.

Pastorale.

24. *p*

Figure 2.36. A score of the song written by the Swedish 18th Century poet Carl Michael Bellman, which was used as a musical and visual structure for the piece *Med lekande kval*. The latter piece finish on the unresolved E7-chord marked in red.

The Score as a Visual structure

As the score is a visual representation of the music, the image of the score also influenced the compositional process to a certain extent. The score was used as a time-grid in ProTools beginning at the first A minor chord. Every chord had its placement in time corresponding to the original but in a stretched version. For instance, as a starting point the length of three quavers (3/8) in the first bar in Figure 2.36 was given the value of ten seconds in the time-grid in ProTools (see Figure 2.37). Within these ten seconds, the sound material was centred around the A minor chord but also pitch material from the melody was used, i.e. the tone G#. Throughout the following ten seconds the sound material then was centred round the E7-chord including the tone C as this pitch was present in the original melody. A rough sketch was first made by hand (Figure 2.38). This method was used mostly in the beginning and end of the piece and as a starting point of the compositional process. Later on as the piece developed, different methods were used.



Figure 2.37. The length of three quavers (3/8) in the first bar in the Bellman piece was stretched and given the value of ten seconds in the time-grid in ProTools. Within these ten seconds, the sound material was centred around the specific chord but also pitch material from the original melody was used.



Figure 2.38. An early approximate sketch made by hand for the first ten seconds of the piece.

Editing process

The sound material used in the piece was mostly that of recorded sounds; squeaking door handles, wooden chairs dragged over the floor, bicycle wheels, finger nails on wall-to-wall carpet, rain etc. The sounds were sparsely edited in order to maintain a sense of “musique concrète” throughout the piece and the original sound sources are perceivable to a trained listener.

However, the most important editing technique was that of filtering. All sounds needed to be filtered into either pitches or chords. Due to an early error in the compositional process concerning different sample frequencies in different software programs, the fundamental pitch “A” came to be that of 480 Hz rather than 440 Hz as originally intended. Too much editing that could not be reconstructed had already been made and therefore all pitches and chords had to be based on this new pitch.

One issue during the editing process was that of how to filter the sound material in order to maintain the characteristics of its original, to keep its microscopic spectral frequency fluctuations at the same time it was given a new pitch. The method that was most successful was to filter sounds so that they were given a clearly audible fundamental pitch. In order to do so, the octave relationship was the most useful filtering method, i.e. a pitch of 440 Hz would also be filtered with its octaves 880, 1660, 3320 Hz etc. Occasionally other spectral content

was used in the filtering techniques such as the fifth, fourth and others – all corresponding to the harmonic spectrum and its simple frequency relationships.

The most common technique was, as mentioned above, to filter one fundamental pitch per sound. The next step was to mix these different sounds with different pitches into chords. In this way, different sounds characteristics were present at the same time, constructing a variety of timbres but with an audible pitch or an audible chord perceived.

Orchestration

The material for the piece was orchestrated, similar to that of a traditional instrumental orchestration in order to structure sound material in the frequency domain rather than more usual harmonic figurations.

As an example the melody along with its accompanying chords in the Bellman piece was used in the beginning of *Med lekande kval*. Sound material was filtered into the corresponding pitches of the melody and the chords, and then orchestrated in different frequency registers. For instance the upbeat on E in the Bellman piece (Figure 2.36) was also used as an upbeat in *Med lekande kval* (Sound example 4) in the shape of a sound filtered to a pitch of 360 Hz (which is an “E” in relation to an “A” of 480 Hz).

The tone material of the melody and the corresponding chords in the Bellman piece were used as a pitch-resource and they were as such distributed freely in the frequency register, i.e. the E in the bass register in the fourth beat of bar 1 in the original song was used in a high register in *Med lekande kval* (Sound example 5-11, Figure 2.39).

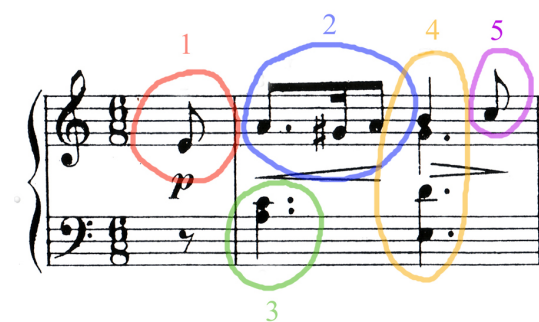


Figure 2.39. The melody along with its accompanying chords in the Bellman piece was used in *Med lekande kval*. Sound material was filtered into the corresponding pitches of the melody and the chords. Then it was orchestrated in different frequency registers (Sound example 5-11).

However, in the middle of the piece, a less rigid compositional technique was used. New chords were introduced in order to develop the harmonic content of the work into different harmonic regions as seen in Figure 2.40 (Appendix 8). This harmonic development was deemed musically important in order to avoid a feeling of predictability inherent in the original song.

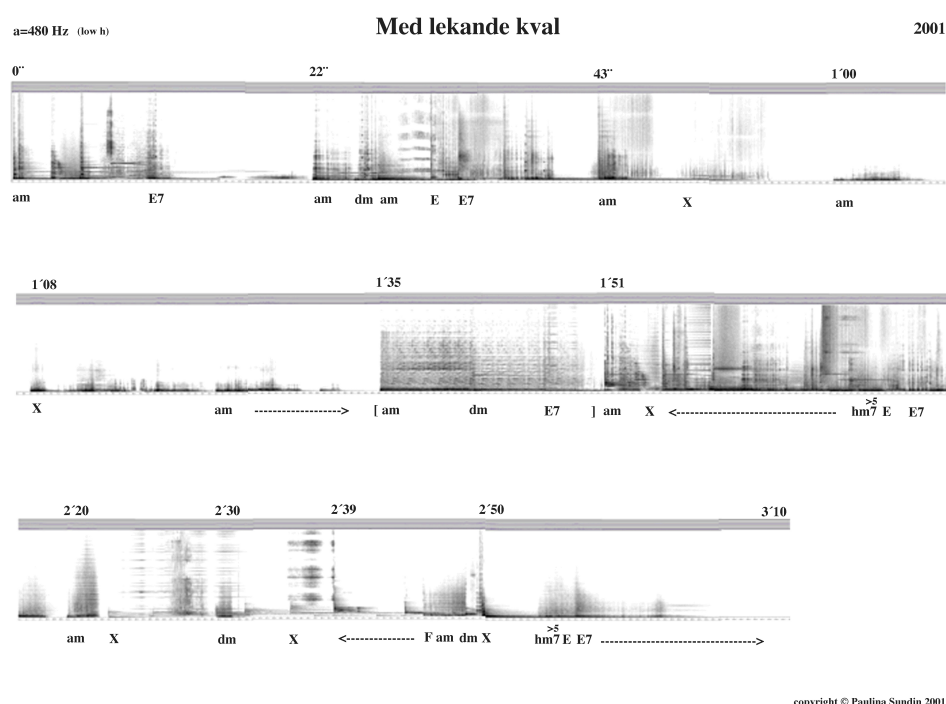


Figure 2.40. A sonogram “score” of the piece *Med lekande kval*. The chords from the imported musical structure, the Bellman piece, are shown underneath the sonogram. Chords not present in the original structure are marked as “X”.

Evaluation

In *Med lekande kval* the imported musical form determined the overall form and the sound material was chosen with the structure in mind. The gestures were kept short and were focused on carrying the harmonic progression forward in a gestural counterpoint fashion.

There was no intention however, that the listener should follow or concentrate on listening to the harmonic content as this was used merely as a compositional tool. Working with harmony was a way of structuring material and to create a sense of forward-motion within the piece.

The inherent properties of the sounds used were important, but most importantly it was the musical structure that directed the choice of sound material and not the other way round. Therefore a careful choice of sound material was made, i.e. the sound to be used needed to be able to be filtered without losing its characteristics or becoming static.

In conclusion, the idea of using an imported musical structure in *Med lekande kval* proved useful and inspiring. Although the chords from the imported structure were altered during the compositional process, *Med lekande kval* gained a clear audible sense of harmonic progression due to the Bellman piece.

2.6 *Within a Dream* (2002)

- fixed media: 7'50

Within a Dream was commissioned for a performance during the conference Future Design Days that took place in Borås, Sweden, in 2002. *Within a Dream* was a collaborative piece with the Swedish composer and soprano Carin Bartosch-Edström, who composed four songs for soprano and recorder, which were performed by herself and the flautist Claudia Müller at the same concert. These songs were used as sound material for the fixed media piece *Within a Dream*. The lyrics for one of the songs used was based on a poem titled *A Dream within a Dream* written by Edgar Allen Poe.

Concept and method

The concept behind *Within a Dream* was to investigate how to incorporate musical material made by another composer and how to relate to the harmony that came with that material. Again, how would the compositional process be effected by the imported material and what effect would the intrinsic harmony of the sound material have on the end result, the final composition?

The difference between *Med lekande kval* and *Within a Dream* is that in the former piece a musical structure was used with no actual sound material derived from the imported structure. In the latter, recordings of songs were used as sound material and the different keys and chords in the songs were used to structure the harmonic progression within the new piece.

The recorded material consisted of selections from the four songs by Bartosch-Edström: *A Dream within a Dream*, *Koral*, *Go not too near a House of Rose* and *Eternity*. The idea was to make a collage of these songs, using the recordings and other sampled material, in order to create a dream-like and surreal atmosphere. This atmosphere would work as a contrast to the live-performance with soprano and recorder, which would take place immediately after the fixed media piece during the premiere.

Within a Dream was intended to be composed as absolute music. However, as the sound material in itself had a strong reference implicit in the sung text, the end result would not be perceived as such. Also, in order to create the “dream-like and surreal atmosphere” the piece had mimetic references to the text used in the title.

Compositional process

Within a Dream was composed in a linear fashion, start to finish. The recordings of the songs were placed in time as a time-grid and the harmony progression was determined by the order of appearance of these songs (see Figure 2.41). New sound material was chosen and edited in such a manner that it would fit in with the traditional harmonic structure, no matter its original spectral content.



Figure 2.41. A simplified model of the compositional process of *Within a Dream* in time. First in the compositional process came the sound material, the four songs by Bartosch-Edström. The idea behind the composition was to use these songs and incorporate them in a specific order based on their key. This musical structure (M) then controlled the time domain (T) as well as the harmony content (H). Other sound material than the four songs was then edited to fit in the structure.

The Musical structure

The musical structure was determined by harmony found in the 19th century romantic song idiom present in the songs by Bartosch-Edström. The keys are those of A minor, C major and A major. The piece begins in A major, goes through the different keys and then eventually ends in C major.

Part of the theme of each song was used as original sound material. The theme found in the first bar of the recorder part (named Claudia in the score) from the song in Figure 2.42 was used as a starting point of *Within a Dream*.

Musik: Carin Bartosch 2002
Text: Edgar Allan Poe

A Dream within a Dream

The musical score for "A Dream within a Dream" is presented in three systems. The first system (measures 1-4) shows Carin singing "Dream is but a dream" and Claudia playing a melody. A red circle highlights the first measure of Claudia's part, which starts with a forte (f) dynamic and a crescendo to piano (p). The second system (measures 5-8) shows Carin singing "Dream is but a dream" and Claudia playing a melody. The third system (measures 9-12) shows Carin singing "Dream is but a dream with-in a dream." and Claudia playing a melody. The score includes various musical notations such as notes, rests, and dynamics.

Figure 2.42. A part of the score of the song *A Dream within a Dream* written by Carin Bartosch-Edström, used as a musical material.

Then the theme from the recorder part in *Eternity* was used, a sampled version played in sputato (Figure 2.43, marked in red brackets).

Eternity

Text: William Blake
Musik: Carin Bartosch Edström 2002

Sopran

he who binds him - self with joy He who binds him - self with

Altblokkflöjt

6

Sopran

joy Does the winged life de - stroy; he who binds him - self with joy

12

Sopran

Does the winged life de - stroy; But He who binds him -

Figure 2.43. A part of the score of the song *Eternity* by Carin Bartosch-Edström.

The Sound material as a Time-grid

The recorded melodies were used as a time-grid in ProTools beginning with the theme of *A Dream within a Dream*. The sound files were placed approximately in time as displayed in Figure 2.44. The harmonic progression of *Within a Dream* then followed the keys of each song (scores in Appendix 9) according to the time-grid.

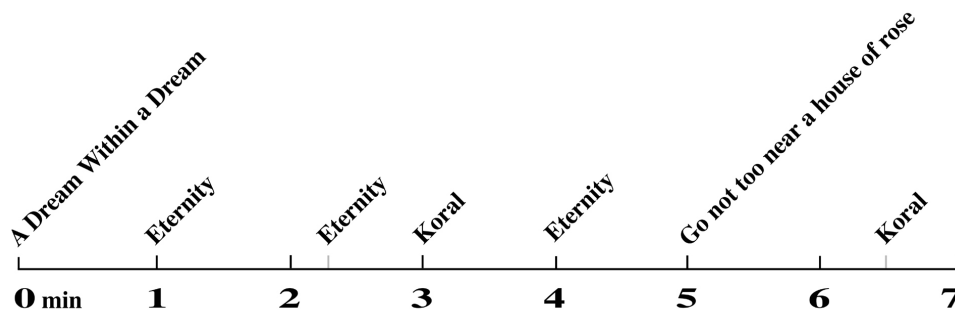


Figure 2.44. The time-grid for *Within a Dream* based on the songs by Carin Bartosch-Edström.

Editing process

The sound material used in the piece was primarily based on the song recordings and additional recordings of voice and recorder. Other sound material included synthesised sounds, such as FM and additive synthesis, and heavily processed sounds. The new sounds were heavily edited in order to create a synthetic feeling as a contrast to the voice and instrument based material.

Again, the most important editing technique was filtering, as the new sounds needed to be adjusted or given a pitch. As the spectrum used was based on a harmonic spectrum, the similar filtering technique to *Med lekande kval* was applied.

Evaluation and conclusion

In *Within a Dream* the imported sound material provided form to the musical structure. The compositional process resembled that of the saxophone and tape piece, *Ti Chor*, in the sense that the original recorded sounds shaped the overall form both in regards to harmonic content and time-structure.

The intent was that the listener would recognize the harmony in the four songs by Bartosch-Edström and also that the harmony and key present in *Within a Dream* would fit together with these songs as they were performed immediately after the fixed media piece. The songs were not utilized as a compositional tool only, as they also were used as sound material. Again, working with harmony was a way of structuring the material and to create a sense of forward-motion within the piece.

The conclusion reached concerning methods used in *Within a Dream* is that incorporating musical material made by another composer made the compositional process easier. As the harmony was based on traditional western harmony, lots of compositional strategies were already implicit in this material concerning musical dissonance and consonance. However, after completing this piece a strong desire to explore another kind of musical harmony emerged.

2.7 *Utresa* (2003)

- fixed media in stereo and 5-channel: 7'00

The composition *Utresa* was part of a project named *Earblink*⁸⁸ created for the premises of the Textile Museum in Borås, Sweden and was exhibited in September 2003 as a textile-sound/music-light-installation where textile and music worked together as an integrated whole. The project was commissioned by Musik i Väst and the Textile Museum in Borås.

Utresa is the name of a textile (Figure 2.45) created by the Swedish textile artist Britt-Marie Hansson, used as a non-musical structure to determine the overall form of the piece sharing the same title.



Figure 2.45. The textile *Utresa* by Britt-Marie Hansson at the Textile Museum in Borås 2003.

⁸⁸ *Earblink* is a direct translation from the Swedish title *Öronblick*.

Concept and method

In the previous pieces with the exception of *Ti Chor*, the focus on harmony has been based on the use of traditional western harmony. *Utresa* was the first electro-acoustic piece in this portfolio to investigate the use of harmony based on an inharmonic spectrum instead of a harmonic one.

The method used as its starting point the research of William A. Sethares concerning the correlation between spectra and scales⁸⁹. Primarily it was his *dissonance curve*⁹⁰ that was of interest as it is based on relevant research concerning sensory dissonance and consonance as mentioned previously in Chapter 1.9-1.11.

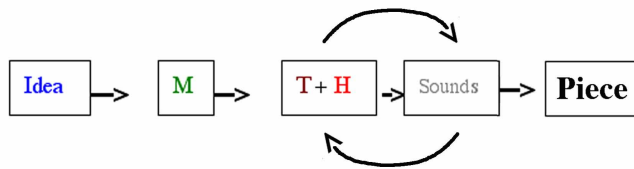
Another important point of departure was the use of a non-musical structure to determine the musical development in time, a kind of time-grid. This grid determined when certain gestural events were to take place within the piece as well as how harmony progressed in time. As mentioned earlier it was the textile with the same name that had been used as a structural device, something that will be discussed later on.

Compositional process

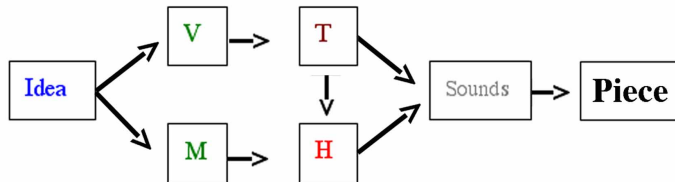
In *Utresa* the compositional process started with the idea of using two different structures in order to organize the temporal domain and the harmonic structure. In earlier pieces a single structure had determined the outcome of both the harmonic structure and the overall time grid. For instance in *Med lekande kval* the imported musical form (the Bellman-piece), was used to structure both the harmonic content as well as how harmony progressed in time. In that instance the imported form was also used to determine when certain gestural events were to take place. However, the time-grid was slightly modified throughout the compositional process in *Med lekande kval* whereas in *Utresa* it remained fixed (Figure 2.46).

⁸⁹ Sethares, W. A., *Tuning, Timbre, Spectrum, Scale* (Springer-Verlag London Limited 1998).

⁹⁰ Sethares, W. A., *Tuning, Timbre, Spectrum, Scale* (Springer-Verlag London Limited 1998), pp. 89-122.



Med lekande kval



Utresa

Figure 2.46. A simplified model of the compositional process of *Utresa* and *Med lekande kval* in time.

In both *Utresa* and *Med lekande kval* the idea behind the composition, i.e. a programmatic idea or a structural idea for the piece came first. In *Med lekande kval* the next step was to select the structural method, in this case the imported musical structure (M) which controlled both the time domain (T) as well as the harmony content (H) and its progression in time.

In *Utresa* there were two different methods used to structure each of these - the visual image (V) that was used to determine when certain gestural events were to take place in the time domain (T) and Sethares' dissonance curve (M) to determine the harmony content (H) within the piece. The time-grid (T) in *Utresa* was used to structure the harmonic progression in time, not the content. The sounds used in *Utresa* then were subservient to the result of these two different structures regarding the placement within the time domain (T) and regarding the frequency content (H). In *Med lekande kval* the compositional process was more flexible and the time-grid was slightly modified when the sound material suggested that a change should be made. Also the harmonic progression was occasionally altered whenever the sound material during the compositional process suggested a different harmonic development.

In *Utresa* the sound material did not alter the results of the two structures whereas in *Med lekande kval* it was allowed to modify the result and therefore have an effect on the time and harmony domain.

How to establish sensory consonance

In *Utresa* I wanted to use a sound with an inharmonic spectrum and from that spectrum derive a scale with intervals that would interact in a sensory consonant manner. I wanted to be able to work with chords based on sound material containing inharmonic spectra and to be able to structure the sound material in time with tonal centres based on the scale steps.

In Chapter 1.11 I describe why Sethares's research was important at this stage and that it was his dissonance curve in particular that was a helpful tool to explore the correlation between inharmonic spectra and scale steps with intervals that would interact in a sensory consonant manner.

Sethares suggests that one should follow six steps⁹¹ (A to F as described on page 41) in order to get the most accurate results from a dissonance curve. *Utresa* used the first four as a starting point. In the following text I will describe how I worked with these four steps in order to create scales and intervals based on the sound I chose for *Utresa* and how I then used this material to create a new kind of harmony.

Choice of sound

After experimenting with a wide range of recorded sounds, the chosen sound for *Utresa* was that of a small wooden drum (Sound example 12). The sound was chosen for its noticeable pitch content and inharmonic spectrum, the latter characterised by a spectrum in which the first partials are clearly audible as separate pitches with an identifiable octave.

Analysis of the spectrum

Regarding spectral analysis of the sound there were some technical details to consider. There were several software programs (such as Audiosculpt and Alchemy) that could analyse the spectral content in a sound but

⁹¹ Sethares, W. A., *Tuning, Timbre, Spectrum, Scale*, Springer-Verlag London Limited, (1998), p. 124.

the accuracy and usefulness of the results are determined primarily by the sample rate, the number of samples analysed, and the windowing procedure used.⁹²

For example, if one would analyse a sound with a sample rate of 22500 samples/second, according to the Nyquist theorem only a frequency content up to 22500 divided by 2 = 11250 Hz would be observed. If the original sound had a lot of spectral content above that register, that information would be unaccounted for in the analysis.

Also it would matter at which specific place in the sound the analysis was to be made. If the sound had a sharp attack and a long sustain, a decision would have to be made depending on what information that was wanted, i.e. the spectral content of the attack or the spectral content of the sustain.

The sound of the drum used for *Utresa* was recorded with a sample rate of 44.1 kHz and was then analysed in both software programs Audiosculpt and Alchemy. The spectrum analysis was made at a specific place in the sound, just after the attack finished, in the sustain mode. In both different programs, the same sixteen partials showed to be the most important ones for the characteristic properties of the sound.

According to Sethares there are other technical details to consider and lots of decisions and investigations to make such as whether to use a hamming window or a rectangular one, choosing the right FFT-size etc., comparing the results and their accuracy compared to the audible input. However, important as this might be according to Sethares, it did not feel relevant at this stage in *Utresa* as the compositional process differs from that of Sethares' more analytical method. His idea was to "play the sound" using a sampler and a keyboard in a more traditional way. Sethares had constructed a sample to play with correlated scale and spectrum.

Simplify the spectrum

By simplifying the analysed spectra preparation is made for the next step, which is drawing the dissonance curve. The idea of simplifying the spectra is to remove non-essential information that might interfere with the outcome of the dissonance curve, and to verify the

⁹² Sethares, W. A., *Tuning, Timbre, Spectrum, Scale*, Springer-Verlag London Limited (1998), p. 125.

accuracy of the analysis. This is because spurious peaks that might show in a spectrum analysis may cause extra minima in the dissonance curve (and thus creating a scale step that is of no use) and missing peaks may cause missing scale steps.

In order to verify the accuracy of the analysis, a comparison between the analysed sound and a re-synthesised version of the sound was recommended. By removing a certain partial from the analysed sound and then re-synthesising it, an aural comparison between the two sounds would reveal if that particular partial had an effect on the audible output. If the re-synthesised sound sounded the same, the partial removed was of no interest and might be excluded, as it was likely to have little or no effect on the overall sound.

After re-synthesising the analysed sound of the wooden drum, adding and removing partials, an audible comparison with the re-synthesised sound and the original showed fourteen partials (see Figure 2.47) to be necessary for the characteristic properties of the sound and therefore two of the original sixteen partials could be omitted without effecting the audible properties of the sound.

Partial 14:	3142 Hz
Partial 13:	2855 Hz
Partial 12:	2630 Hz
Partial 11:	2118 Hz
Partial 10:	1909 Hz
Partial 9:	1575 Hz
Partial 8:	1330 Hz
Partial 7:	870 Hz
Partial 6:	681 Hz
Partial 5:	520 Hz
Partial 4:	476 Hz
Partial 3:	346 Hz
Partial 2:	227 Hz
Partial 1:	173 Hz



Figure 2.47. The fourteen chosen partials of the wooden drum spectrum.

Draw the dissonance curve

The first step towards working with sensory consonant chords was to see how the spectrum of the analysed wooden drum would work with Sethares' dissonance curve. Would there be any relevant results from this and if so, how could those results be treated in a meaningful way?

In order to use the Sethares' dissonance curve the amplitudes of the partials of the wooden drum needed to be recalculated from decibel to a number between 0 and 1. The frequency of the fourteen partials with their respective amplitudes was then used to create the following dissonance curve as seen in Figure 2.48.

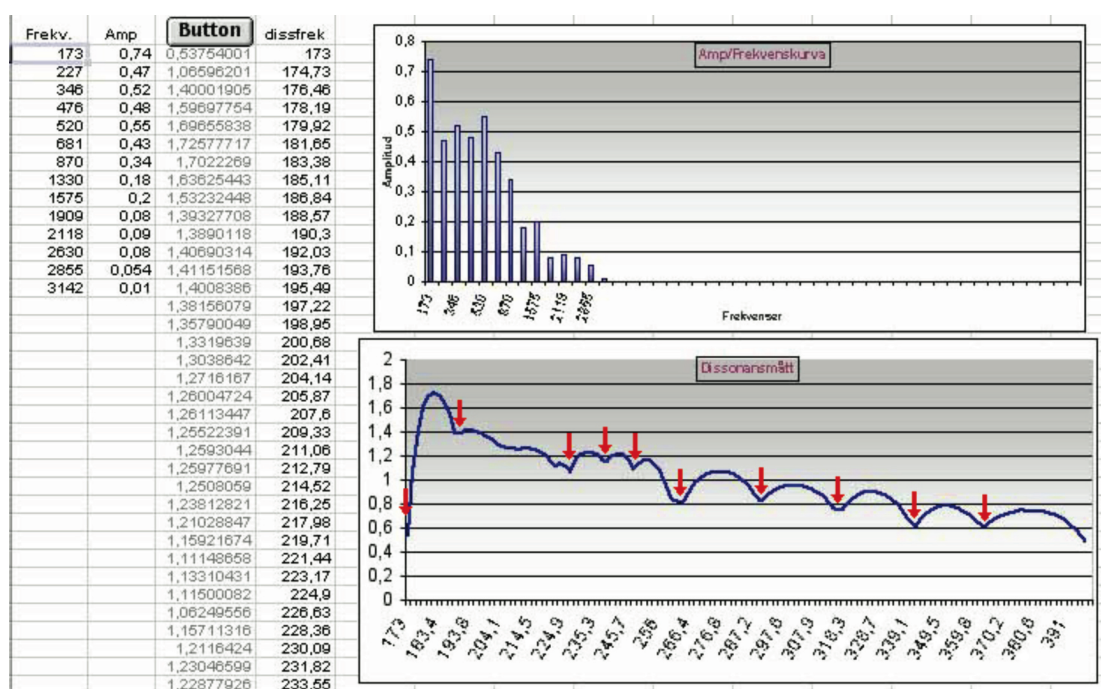


Figure 2.48. The fourteen most prominent partials and their amplitudes from the analysed sound sample of the wooden drum are used to create the dissonance curve based on William A. Sethares' programming in Basic. The layout was made by programmer Rasmus Ekman. The dissonance curve compared the original spectrum with its transpositions played simultaneously within the range of about a normal octave. The result was a long list of numbers linked to one frequency each where the minima were estimated to be the most suitable using as scale steps.

According to Sethares the minima of a dissonance curve occur at intervals

which are good candidates for notes of a scale, since they are intervals of minimum of dissonance (or equivalently, intervals of maximum consonance).⁹³

⁹³ Sethares, W. A., *Tuning, Timbre, Spectrum, Scale*, Springer-Verlag London Limited, (1998), p. 90.

The minima of the dissonance curve occurred at nine different places within the range of an octave ($2 \cdot F$) including the fundamental frequency. Eight of these were selected as scale steps thus creating a scale of nine steps with an octave at $1.97 \cdot F$ (see Figure 2.49, Sound example 13).

<i>Freq 1.0</i>	Cent	index	<i>Scale 1.0</i>
173			F
164,991243	164,991243	1,1	
190,3			↓F#
302,4521414	467,443384	1,31	
226,63			↓A#
90,11465391	557,558038	1,38	
238,74			↓A#
61,61140694	619,169445	1,43	
247,39			H
105,6590962	724,828542	1,52	
262,96			C
162,9193124	887,747854	1,67	
288,91			D
158,3821897	1046,13004	1,83	
316,59			D#
127,6123338	1173,74238	1,97	
340,81			↓F
110,6237313	1284,36611	2,1	
363,3			(↓F#)

Figure 2.49. The selected scale steps with an additional extra scale step at $2.1 \cdot F$. Column 1 show the frequencies for each scale step and the cent value between each step. Column 2 shows the cent value related to the fundamental frequency 173 Hz. $[(\text{Lg } F_2 - \text{Lg } F_1) \cdot 3986]$. Column 3 shows the index value for each scale step related to the fundamental $[F_2/F_1, F_3/F_1 \dots F_{10}/F_1]$. Column 4 shows the scale step in relation to traditional 12 note chromatic scale.

Creating an instrument

As mentioned earlier Sethares' research was based on using the original, analysed sound as the basic sound material for the piece. In *Utresa* this was not the case. The original sound is however present in the composition as sound material but only at certain positions in the piece in order to mark out the time-grid. The spectrum of the analysed wooden drum was primarily used to determine the harmonic content of the piece.

In order to be able to use the scale chosen from the dissonance curve new tools needed to be constructed. The spectrum of each scale step had to be superimposed on to other sounds and for *Utresa* a resonant filtering technique was chosen.

In Max/MSP a resonance filter was constructed featuring the ability to transpose up to fifty frequencies with individually set amplitudes (Figure 2.50). It also allowed interpolation in time between a spectrum and transposed versions of that spectrum. In this patch the fourteen frequencies of the wooden drum were used along with the scale step transpositions.

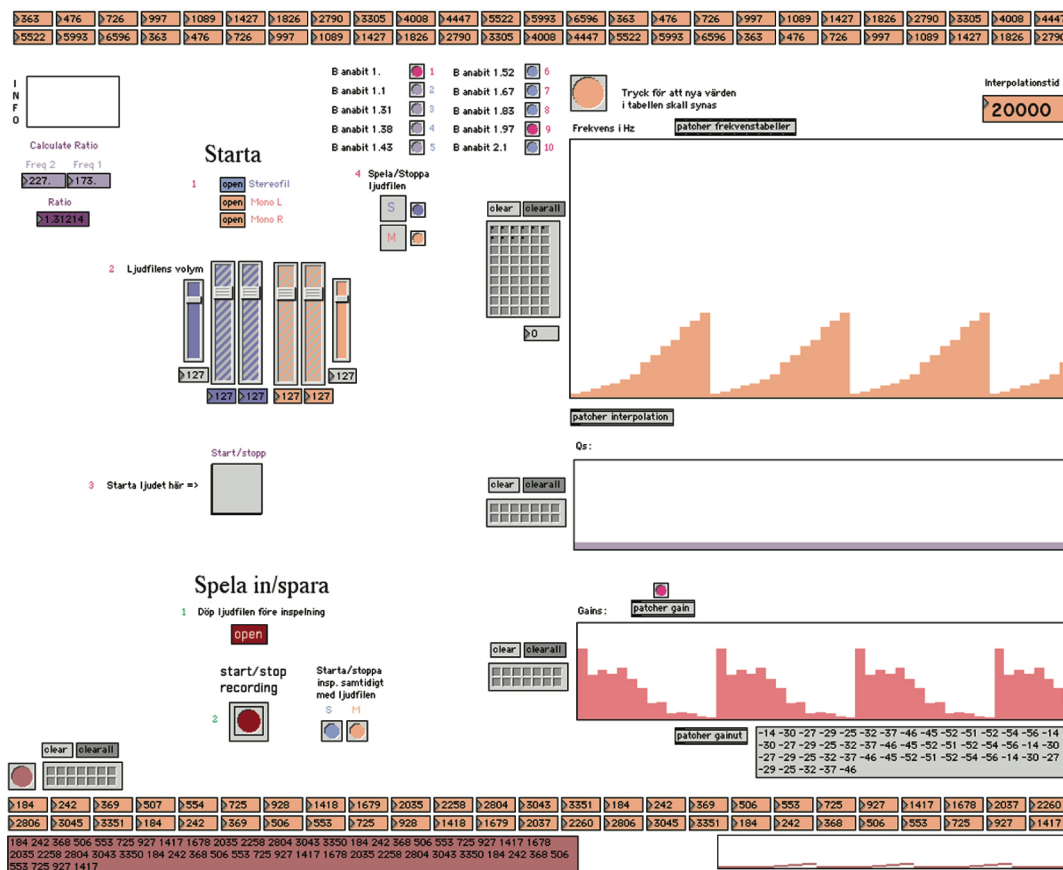


Figure 2.50. The resonance filter patch built in Max/MSP. The patch was created in such a manner so that every parameter would be accessible for each frequency, for instance parameters like amplitude, Q-value of the filter and the interpolation frequency.

Also an additive synthesis tool was constructed using sine tone generators (Figure 2.51). This particular patch consisted of twenty-eight sine tone generators, allowing two spectra consisting of fourteen partials each to be played simultaneously. Each partial had its own envelope and the length of the envelope was controlled by the variable value of a slider. Each partial also had its own LFO. As with the resonance filter it was possible to interpolate in time between a spectrum and its transpositions. This tool was used to examine which intervals would work together as chords by looking for sensory consonance. With the matrix-object it was possible to play one spectrum in the left channel and another in the right channel. More interesting was to mix the partials of two spectra as seen in the matrix-object in Figure 2.51 and test which partials together would create sensory dissonance.

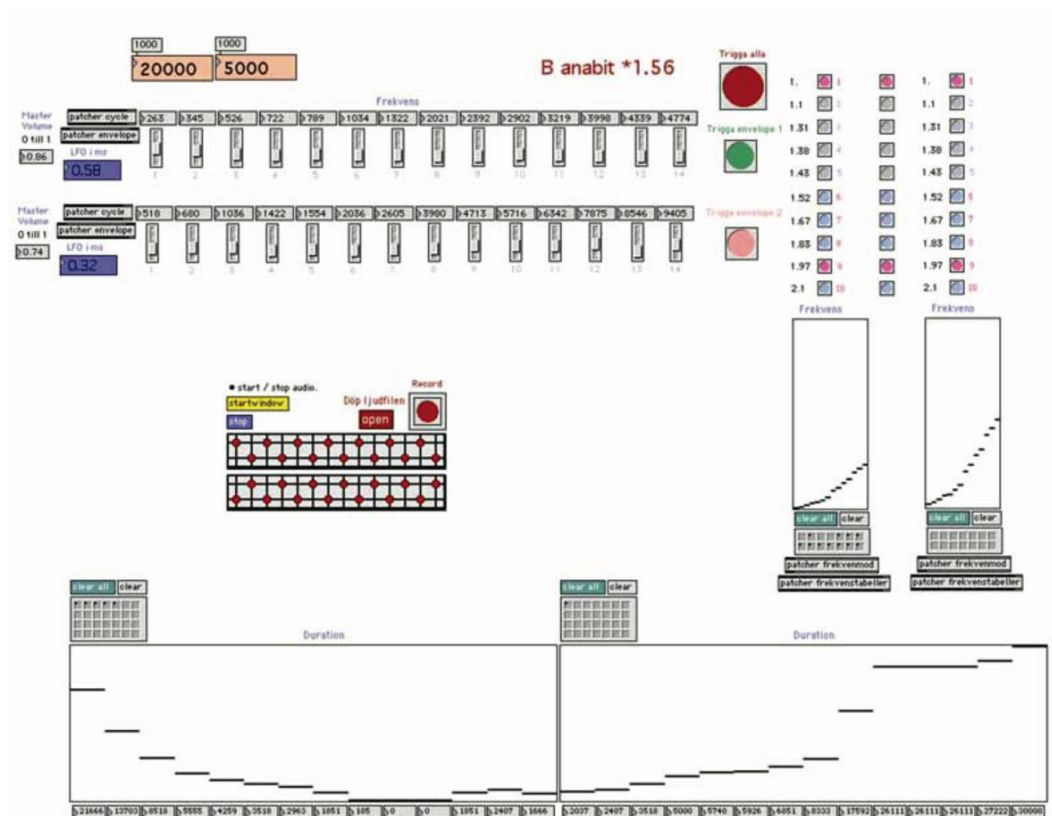


Figure 2.51. The additive synthesis patch built in Max/MSP.

Constructing the overall Time-grid

The time-grid structure of the music was calculated using a photo image of the textile *Utresa*. The image was turned 90 degrees clockwise in order to use certain details in the textile to specify different events in the music (see Figure 2.52). First the duration of the whole piece was set at seven minutes long. Then the horizontal line of the image was used as a time scale of this duration. The fourteen white cubes seen at the lower part of the image were given the roll of setting the tonal centre for when they occurred on the time scale (Sound example 14).

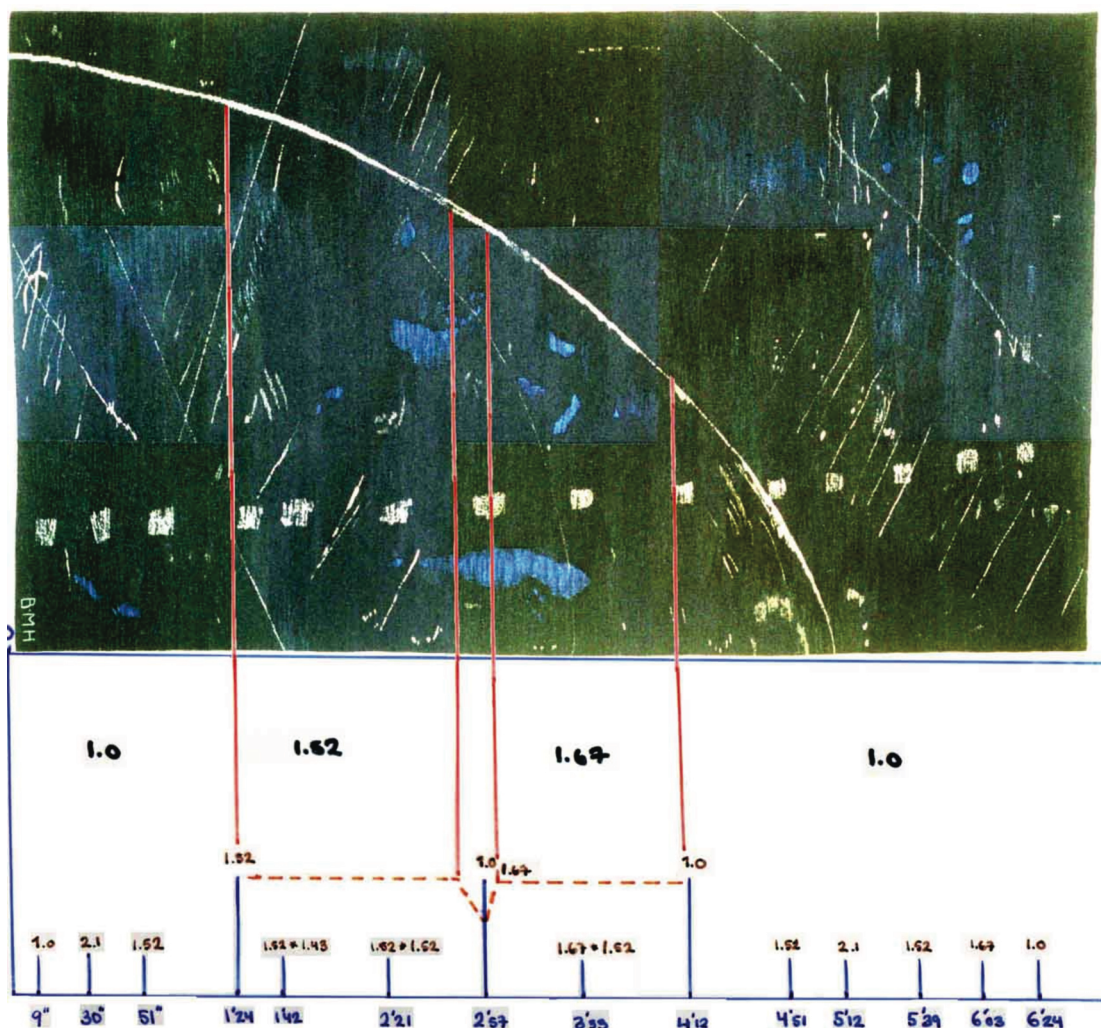


Figure 2.52. Tonal centres throughout the composition: Scale step 1 and two of its transpositions (1.0, 2.1, 1.52), scale step 6 and transpositions (1.52, 1.52×1.43 , 1.52×1.52), Scale step 1 (1.0), scale step 7 and transpositions (1.67 , 1.67×1.52), scale step 1 and transpositions (1.0, 1.52, 2.1, 1.52, 1.67, 1.0). [Sound example 14]

The point at which transition from the initial spectrum (1.0) to the 6th scale step (1.52) occurred was determined by the point at which the curving white line crossed from dark blue to black as seen in Figure 2.52. This also determined the changes from spectrum 1.52 and the scale based on that spectrum (see Figure 2.53) to other scale steps, for instance the 7th scale step (1.67) and the original spectrum 1.0 (at 4'12 in the piece as seen in Figure 2.52). These tonal centres were chosen based on their aurally perceived and subjectively judged qualities.

<i>Freq 1.0</i>	Cent	index	<i>Scale 1.0</i>	<i>Frek 1.52</i>	<i>Skala 1.52</i>	<i>Frek 1.67</i>	<i>Skala 1.63</i>
173			F				
164,991243	164,991243	1,1					
190,3			↑F#				
302,4521414	467,443384	1,31					
226,63			↓A#				
90,11465391	557,558038	1,38					
238,74			↑A#				
61,61140694	619,169445	1,43					
247,39			H				
105,6590962	724,828542	1,52					
262,96			C	262,96	C		
162,9193124	887,747854	1,67					
288,91			D	289,26	D	288,91	D
158,3821897	1046,13004	1,83					
316,59			D#	344	F	317,8	↑D#
127,6123338	1173,74238	1,97					
340,81			↓F	362,88	↓F#	378	↑F#
110,6237313	1284,36611	2,1					
363,3			(↓F#)	376	↑F#	398,7	↑G
				399,7	↑G	413	G#
				439	A	439	A
				481	↓H	482	↓H
				518	C	528,7	C
				552	(C#)	569	↑C#
						606,7	(↓D#)

Figure 2.53. The original scale and the transposed scales beginning from scale step 1.52 and 1.67. Column 1 to 4 as described in Figure 2.49. Column 5 and 6 show the transposed scale beginning at 262.96 Hz (scale step 1.52). Column 7 and 8 show the transposed scale beginning at 288.91 Hz (scale step 1.67).

Using smaller Time-grids to control the choice of sound material

In order to determine the choice of sounds and the expression and atmosphere in the music, the textile *Utresa* was used again as a point of departure. However, this time cut up into slices. The idea was that the textile would be lighted with a mobile light that followed the course of the music in the textile in time, i.e. synchronized light and sound. When the music was played, the light would focus on the parts in the textile that had been used as a source of inspiration for the particular music that was heard at the same time. In order to do this, a light-score that functioned as a model upon which the music was composed was constructed (Figure 2.54).

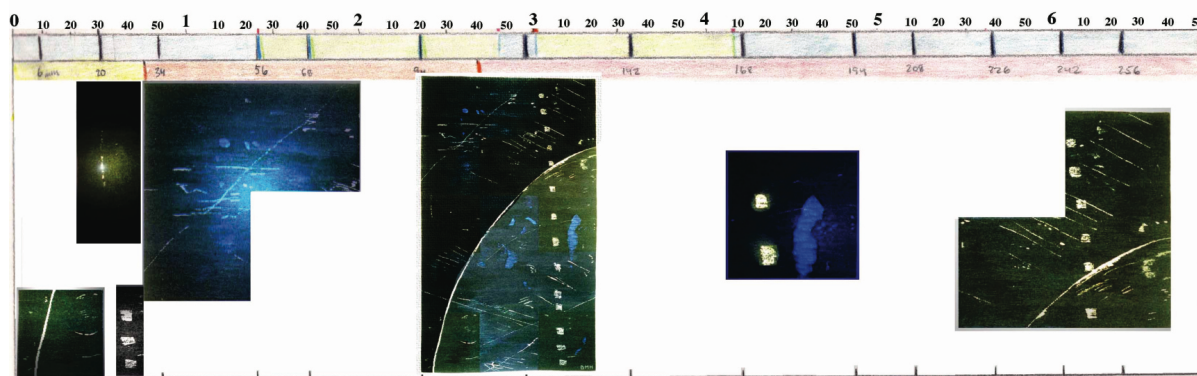


Figure 2.54. A approximate light-score for the piece with the focus points in the textile *Utresa* throughout the musical composition on a time scale.

Difficulties encountered during the compositional process

To work with the scale based on the result from Sethares' dissonance curve involved some difficulties that needed to be overcome. For instance, the octave of the scale had an index of 1.97 and not 2.0 as in traditional western music. How then should the scale be transposed and how would the sounds be filtered in order to work with the whole frequency range of 20 Hz to 20 kHz?

The original spectra covered frequencies between 173 Hz to 3142 Hz. In order to enhance sounds that had been filtered to the original spectra, the frequency 173 Hz was divided by 1.97 = 87.82 Hz or 173 divided by $2 \times 1.97 = 44.58$ Hz and filtered onto the sound. The result from this division did not always sound good depending on which sound was filtered (the different spectra inherent in each sound effected the end result). With certain sounds a traditional western octave seemed to work better i.e. 173 Hz divided by 2.0. I therefore included the traditional western octave in the filtering process when I thought it appropriate.

Multi-channel version

As with *Clandestine Parts*, the multi-channel mix was planned from the stereo version. Each separate stereo sound file was given a placement in a loudspeaker configuration according to Figure 2.55.

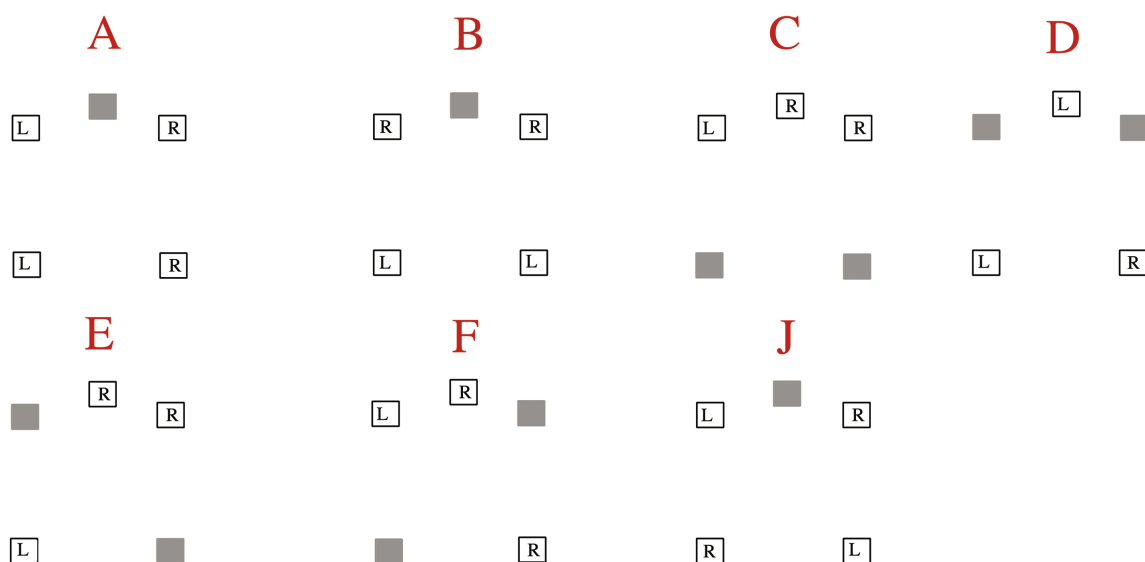


Figure 2.55. Seven different loudspeaker configurations.

A similar mixing method to *Clandestine Parts* was used with the difference that *Utresa* was mixed to 5.0-format using different loudspeaker configurations.

Evaluation

Utresa was the first attempt since *Ti Chor* to work systematically with inharmonic spectra and to create a harmony throughout the piece based on that. The process was time-consuming and many calculations had to be made before I could begin composing with the sound material. The most time-consuming task was however, to filter all the sounds in the piece to fit with the spectral content used as a basis for the dissonance curve and all its transpositions and scale steps (see Figure 2.56 and Appendix 10).

Creating scales based on Sethares' dissonance curve turned out to be a fruitful way of constructing a consistent harmony throughout a piece. As *Utresa* was a first attempt at using this new harmonic method I continued to research its application in my music in my next two compositions: *Joker* and *The Ringing Stone of Håga*.

B analt Spectrum Transp. 1.0	Frequencies		Cent	Index	Frequencies		Cent	Index	Frequencies		Cent	Index	Index/Scale												
	Freqs	Cent			Freqs	Cent			Freqs	Cent															
173	470,3673	1,31213873	1,1	190,3	256,63	1,38	238,74	1,43	247,28	1,52	262,96	1,67	288,91	1,83	316,59	1,97	340,81	2,1	363,3	173	470,3673	1,31213873	166,991243	164,991243	1,1
227	470,3673	1,31213873	2	240,7	297,37	1,38	313,26	1,43	324,61	1,52	345,04	1,67	370,09	1,83	415,41	1,97	447,19	2	476,7	227	470,3673	1,31213873	166,991243	164,991243	1,1
346	1748,44896	2,74566474	2	380,6	453,26	1,38	477,48	1,43	494,78	1,52	525,92	1,67	572,82	1,83	633,18	1,97	681,62	2	726,6	346	1748,44896	2,74566474	302,431444	289,431444	1,31
475	1748,44896	2,74566474	3	525,5	622,25	1,38	655,5	1,43	678,25	1,52	722	1,67	783,25	1,83	869,25	1,97	935,75	3	997,5	475	1748,44896	2,74566474	302,431444	289,431444	1,31
519	2369,52876	3,93063584	3	570,9	679,89	1,38	712,17	1,43	741,17	1,52	788,88	1,67	866,73	1,83	949,77	1,97	1024,43	3	1089,9	519	2369,52876	3,93063584	407,542777	389,542777	1,43
680	2369,52876	3,93063584	3	748	890,9	1,38	938,4	1,43	972,4	1,52	1035,6	1,67	1135,6	1,83	1244,4	1,97	1398,6	3	1488	680	2369,52876	3,93063584	407,542777	389,542777	1,43
870	3529,51881	5,02880173	3	957	1139,7	1,38	1200,6	1,43	1244,1	1,52	1324,4	1,67	1452,9	1,83	1595,1	1,97	1713,9	3	1827	870	3529,51881	5,02880173	502,880173	480,880173	1,67
1329	3529,51881	5,02880173	3	1461,9	1740,99	1,38	1842,02	1,43	1900,47	1,52	2020,08	1,67	2215,43	1,83	2432,07	1,97	2616,13	3	2796,9	1329	3529,51881	5,02880173	502,880173	480,880173	1,67
1574	4156,4066	11,0346821	3	1731,4	2061,94	1,38	2172,12	1,43	2250,82	1,52	2392,48	1,67	2628,58	1,83	2880,42	1,97	3102,78	3	3305,4	1574	4156,4066	11,0346821	509,82559	487,82559	1,97
1909	4156,4066	11,0346821	3	2099,9	2500,79	1,38	2634,42	1,43	2753,87	1,52	2901,68	1,67	3186,03	1,83	3493,47	1,97	3760,73	3	4008,9	1909	4156,4066	11,0346821	509,82559	487,82559	1,97
2118	4711,09185	15,2023121	3	2329,8	2822,84	1,38	3208,74	1,43	3279,36	1,52	3537,06	1,67	4012,46	1,83	4447,8	1,97	4852,9	3	5233	2118	4711,09185	15,2023121	569,152121	547,152121	2,1
2630	4711,09185	15,2023121	3	2693	3445,3	1,38	3829,4	1,43	3760,9	1,52	3997,6	1,67	4392,1	1,83	4812,9	1,97	5181,1	3	5523	2630	4711,09185	15,2023121	569,152121	547,152121	2,1
2854	4852,58775	16,497108	3	3198,4	3786,74	1,38	3938,52	1,43	4081,22	1,52	4338,08	1,67	4766,18	1,83	5222,82	1,97	5693,4	3	5984,8	2854	4852,58775	16,497108	569,152121	547,152121	2,1
3141	5018,46103	18,1560894	3	3455,1	4147,1	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	3141	5018,46103	18,1560894	569,152121	547,152121	2,1
3698	5018,46103	18,1560894	3	3698	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	3698	5018,46103	18,1560894	569,152121	547,152121	2,1
4174	5018,46103	18,1560894	3	4174	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	4174	5018,46103	18,1560894	569,152121	547,152121	2,1
4743	5018,46103	18,1560894	3	4743	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	4743	5018,46103	18,1560894	569,152121	547,152121	2,1
5312	5018,46103	18,1560894	3	5312	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	5312	5018,46103	18,1560894	569,152121	547,152121	2,1
5881	5018,46103	18,1560894	3	5881	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	5881	5018,46103	18,1560894	569,152121	547,152121	2,1
6450	5018,46103	18,1560894	3	6450	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	6450	5018,46103	18,1560894	569,152121	547,152121	2,1
7019	5018,46103	18,1560894	3	7019	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	7019	5018,46103	18,1560894	569,152121	547,152121	2,1
7588	5018,46103	18,1560894	3	7588	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	7588	5018,46103	18,1560894	569,152121	547,152121	2,1
8157	5018,46103	18,1560894	3	8157	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	8157	5018,46103	18,1560894	569,152121	547,152121	2,1
8726	5018,46103	18,1560894	3	8726	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	8726	5018,46103	18,1560894	569,152121	547,152121	2,1
9295	5018,46103	18,1560894	3	9295	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	9295	5018,46103	18,1560894	569,152121	547,152121	2,1
9864	5018,46103	18,1560894	3	9864	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	9864	5018,46103	18,1560894	569,152121	547,152121	2,1
10433	5018,46103	18,1560894	3	10433	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	10433	5018,46103	18,1560894	569,152121	547,152121	2,1
11002	5018,46103	18,1560894	3	11002	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	11002	5018,46103	18,1560894	569,152121	547,152121	2,1
11571	5018,46103	18,1560894	3	11571	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	11571	5018,46103	18,1560894	569,152121	547,152121	2,1
12140	5018,46103	18,1560894	3	12140	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	12140	5018,46103	18,1560894	569,152121	547,152121	2,1
12709	5018,46103	18,1560894	3	12709	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	12709	5018,46103	18,1560894	569,152121	547,152121	2,1
13278	5018,46103	18,1560894	3	13278	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	13278	5018,46103	18,1560894	569,152121	547,152121	2,1
13847	5018,46103	18,1560894	3	13847	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	13847	5018,46103	18,1560894	569,152121	547,152121	2,1
14416	5018,46103	18,1560894	3	14416	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	14416	5018,46103	18,1560894	569,152121	547,152121	2,1
14985	5018,46103	18,1560894	3	14985	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	14985	5018,46103	18,1560894	569,152121	547,152121	2,1
15554	5018,46103	18,1560894	3	15554	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	15554	5018,46103	18,1560894	569,152121	547,152121	2,1
16123	5018,46103	18,1560894	3	16123	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	16123	5018,46103	18,1560894	569,152121	547,152121	2,1
16692	5018,46103	18,1560894	3	16692	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	16692	5018,46103	18,1560894	569,152121	547,152121	2,1
17261	5018,46103	18,1560894	3	17261	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	17261	5018,46103	18,1560894	569,152121	547,152121	2,1
17830	5018,46103	18,1560894	3	17830	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	17830	5018,46103	18,1560894	569,152121	547,152121	2,1
18399	5018,46103	18,1560894	3	18399	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774,32	1,67	5245,47	1,83	5748,03	1,97	6187,77	3	6596,1	18399	5018,46103	18,1560894	569,152121	547,152121	2,1
18968	5018,46103	18,1560894	3	18968	4334,58	1,38	4334,58	1,43	4481,63	1,52	4774														

2.8 *Joker* (2003)

- fixed media in stereo and 5.1-channel: 13'00

Joker was also part of the project named *Earblink*, exhibited in September 2003 at the Textile Museum in Borås in Sweden.

Joker was a joint collaboration with the Swedish textile artist Britt-Marie Hansson who created four different large textiles (see Figure 2.57) that together with the music formed an installation. Unlike *Utresa*, *Joker* was based on a collaborative approach and not on the interpretation of a physical textile that already existed, and therefore the approach to the compositional process was somewhat different.



Figure 2.57. The textile series *Joker* by Britt-Marie Hansson.

Idea and method

Britt-Marie Hansson and I together created a theme for which I would compose thirteen minutes of music and she would create four textiles. The idea was that I would elucidate the structure of the textiles in a time perspective and that the textiles would reveal clues to the symbols portrayed in the music. We would also use synchronized light and sound, i.e. the textiles would be lighted with a mobile light that followed the course of the music in the textile in time.

In *Joker* I wanted to use a harmony based on different spectra, each spectrum linked to a theme. The theme was based on playing cards and the different card families clubs, diamonds, hearts and spades.

As in *Utresa*, there are elements in *Joker* that were based on research made by William Sethares mentioned in the previous chapter. However the idea for this piece was to combine harmony based on several different spectra. One of the key research questions was: is there a way to combine the different sets of harmonies and maintain a feeling of unity throughout the whole composition?

Compositional process

The different themes determined the time-domain and the sounds chosen for the musical structure controlled the harmonic development in the piece (see Figure 2.58). The sound sources that determined the harmonic structure, where concrete sounds with different characters. Also a harmonic spectrum was used in order to portray the theme of spades.

All sound material used in the piece were processed to work with the harmonic structure based on the concrete sounds and the harmonic spectrum.

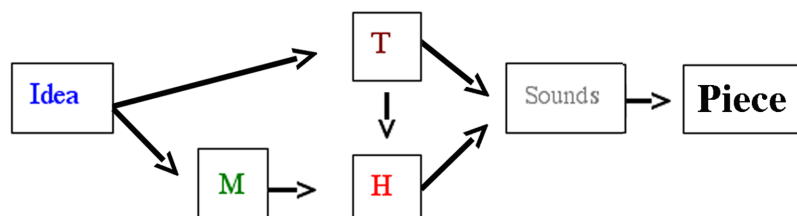


Figure 2.58. A simplified model of the compositional process for *Joker*.

Constructing themes

Britt-Marie Hansson and I gave each card family different characters. For instance, clubs were to have a playful character, unpredictable and clever. Diamonds would be safe and reliable. Hearts would portray joy, stability and lust. Spades would be power, strength and dominance. I had these characteristics in mind when I explored sound sources and spectra for each theme.

In the early stages of creating *Joker* we exchanged material and ideas through post as I lived in Stockholm and Britt-Marie Hansson lived in Gothenburg (south of Sweden). The material consisted of sound files and sketches (see Figure 2.59).

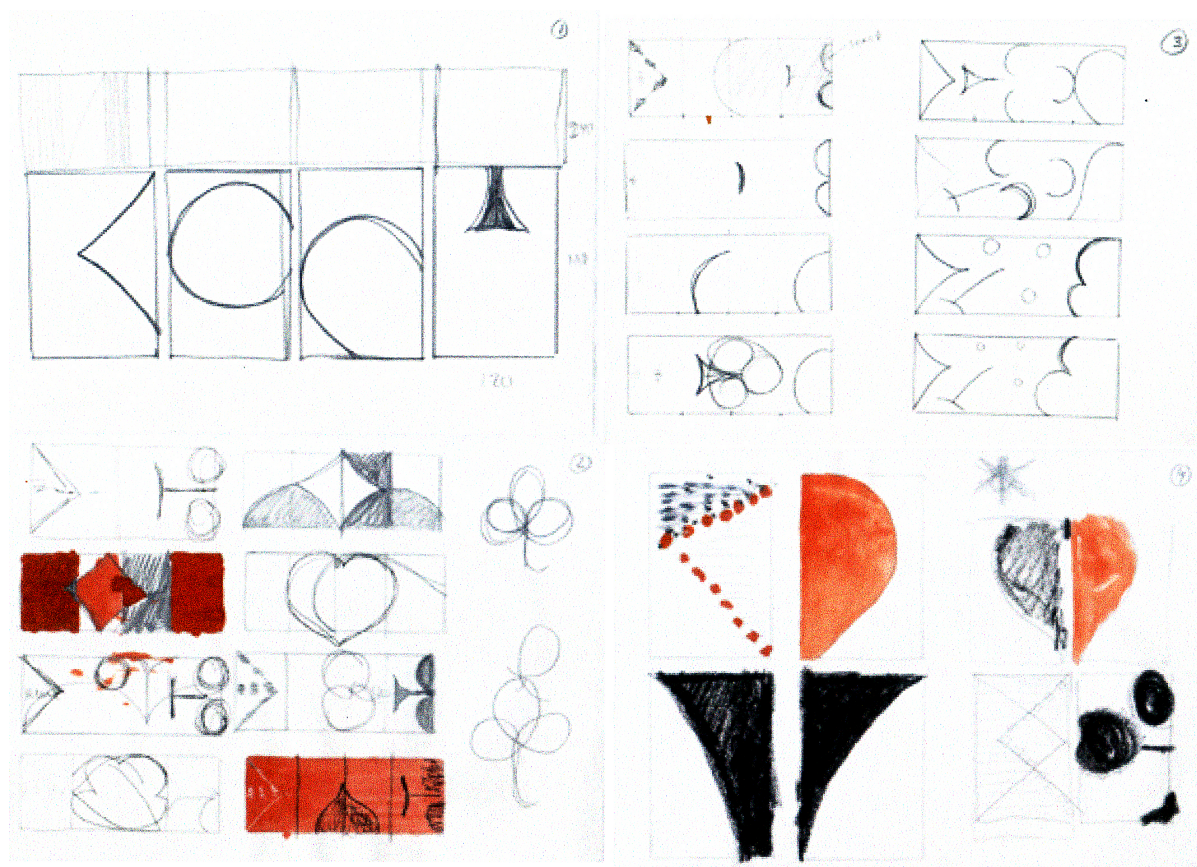


Figure 2.59. Sketches for *Joker* in an early stage.

Clubs

When we had agreed upon the sound material for the theme of clubs and what sketch to use (see Figure 2.60) I did the same preparations as in *Utresa* in order to use a dissonance curve (as described in page 94-96). The sound chosen for clubs I found when I listened to old processed material on DAT-tapes, material that I had made for other pieces but never used. This particular sound, originally most likely a woodblock sound, I thought had that playful character that I wanted for clubs when played together with itself with an interval of a major second (Sound example 15).

Mina arbetssluss. Allt kom inte med i kopian så jag har fyllt i med bläck. Du ser kanske i stora delar att jag har tagit lite här o där från "färgskisserna".

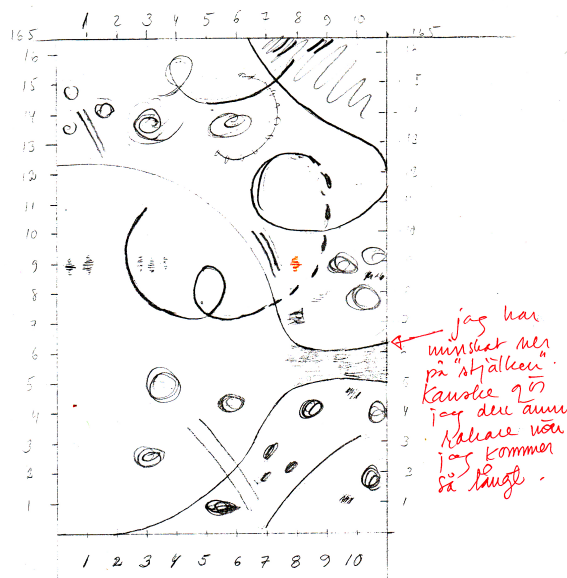


Figure 2.60. A Sketch for the theme clubs in an early stage.

The result of the analysis of the sound for clubs rendered a dissonance curve (see Figure 2.61).

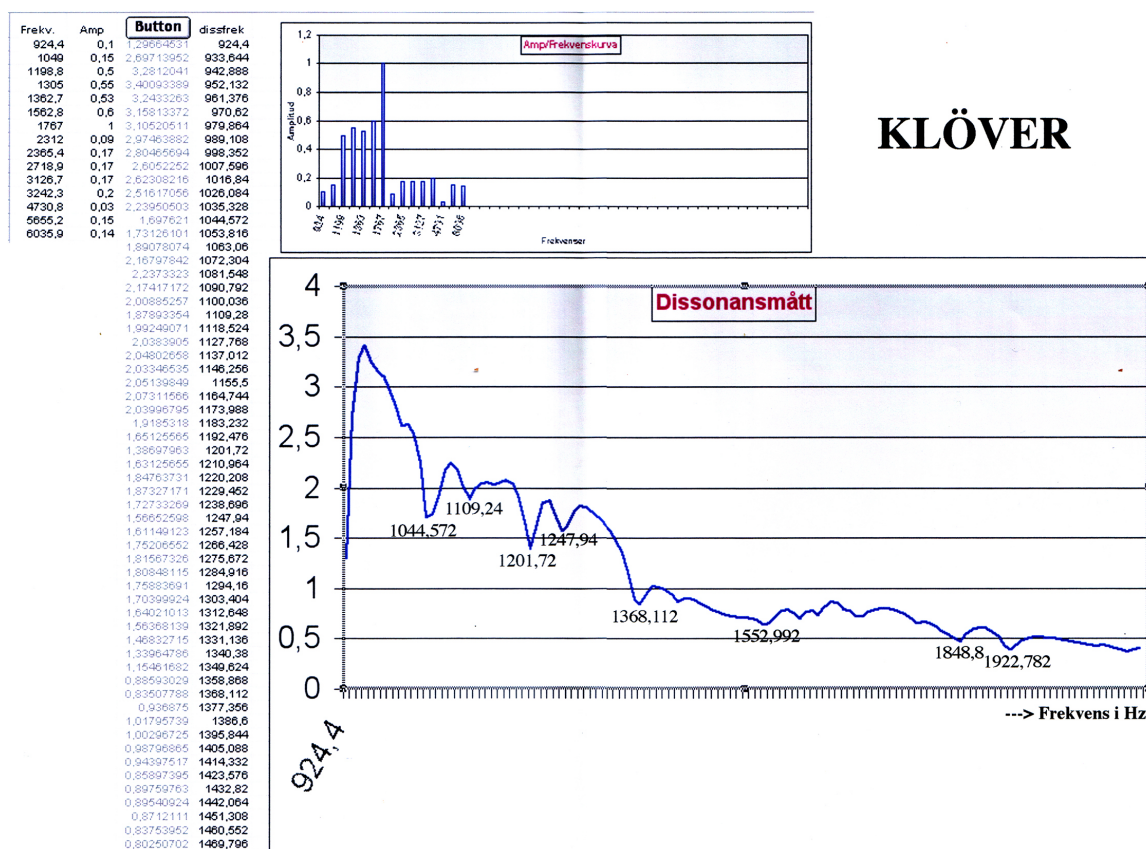


Figure 2.61. The fifteen most prominent partials and their amplitudes from the analysed sound sample of clubs were used to create the dissonance curve.

When I developed the theme for clubs I was inspired by the swirls and floating movements from Hansson's early sketch and tried to construct the sound material to illustrate this motion using different delays, reverb and transpositions of the original sound (Sound example 16).

As I was working with this I received more sketches (see Figure 2.62), edited the material according to my impressions of the new sketches and then sent the new sounds to Hansson to listen to. We continued this process throughout the project for each theme.

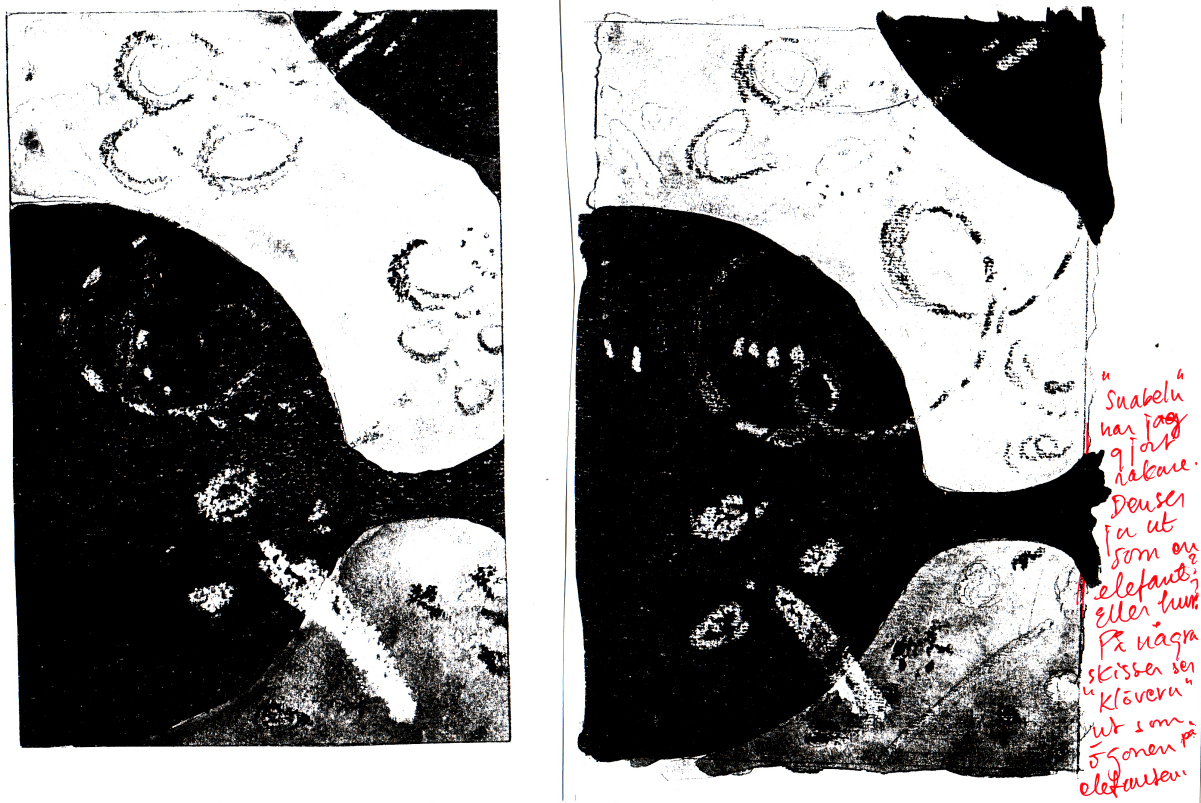


Figure 2.62. Sketches for the theme clubs in a later stage.

Diamonds

The theme for diamonds was created using the idea of layers. I visualised a solid, reliable building made of many bricks in various shapes, a building that would last hundreds of years because of its solid construction. This idea made me think of a sound made by brick material and I recorded lots of sound material before I found what I was looking for in a terracotta pot sound. Hansson's interpretation of the idea of layers can be seen in Figure 2.63.



Figure 2.63. The image portraying the theme of diamonds.

Diamonds were then illustrated with the sound of a terracotta pot whose spectrum generated a dissonance curve from which nine scale steps were elaborated with (Figure 2.64).

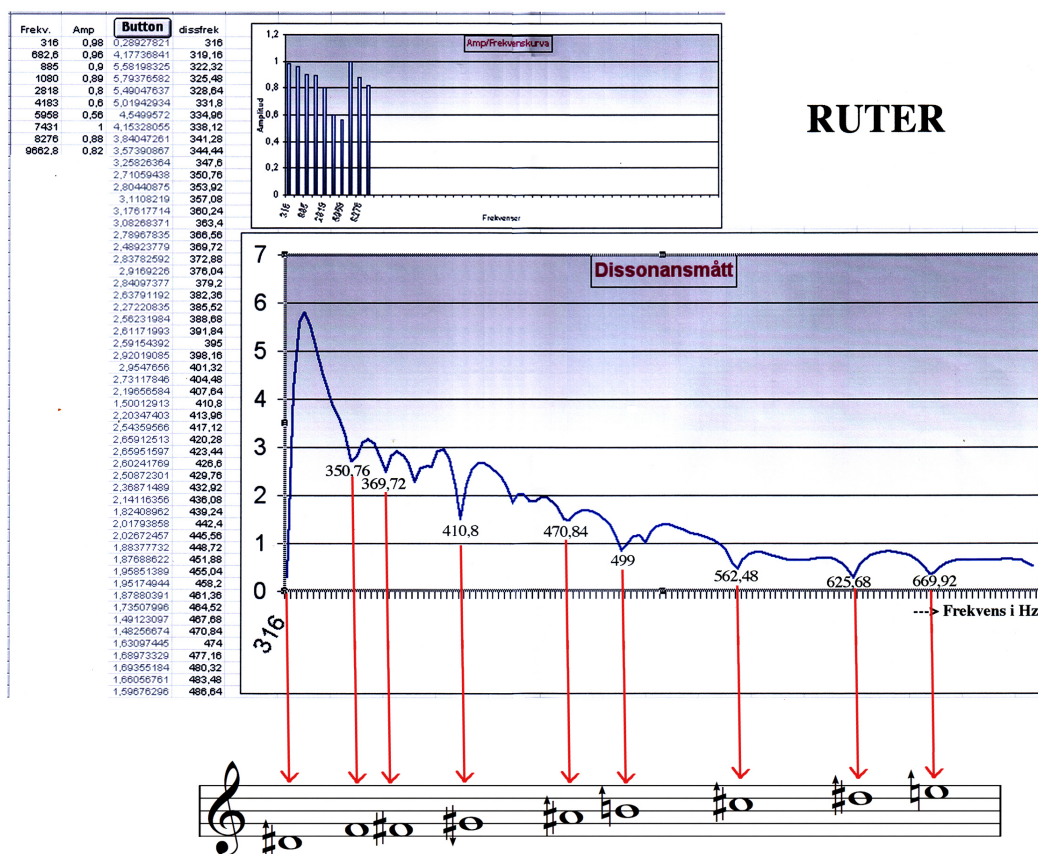


Figure 2.64. The ten most prominent partials and their amplitudes from the analysed sound sample of diamond were used to create the dissonance curve. Nine scale steps were chosen from the dissonance curve.

A table of frequencies for the nine scale steps was calculated (see Figure 2.65).

T ana Spektrum Transp.100	Frekvens	Cent	Index	Frekvens	Cent	Index	Frekvens	Cent	Index	Frekvens	Cent	Index	Frekvens	Cent	Index	Frekvens	Cent	Index	Frekvens	Cent	Index	
	316,211	1332,05323	2,15865356	1,10925932	350,76	1,16921929	369,72	1,29913254	410,8	1,46900576	470,84	1,57806022	499	1,77881225	562,48	1,97867879	625,68	2,11858537	669,92	316,211	1332,05323	2,15865356
	682,59	1782,3508	2,79996585	757,16932	798,09739	1,6921929	798,09739	1,6921929	886,77488	1,46900576	1016,3804	1,57806022	1077,1681	1,77881225	1214,1995	1,97867879	1350,6264	1446,1232	682,59	1782,3508	2,79996585	
	885,38	2127,78488	3,41833459	982,11602	1035,2034	1,6921929	1035,2034	1,6921929	1150,226	1,46900576	1318,3359	1,57806022	1397,183	1,77881225	1574,9248	1,97867879	1751,8826	1875,7531	885,38	2127,78488	3,41833459	
	1080,915	3786,55656	8,91177094	1199,015	1263,8267	1,6921929	1263,8267	1,6921929	1404,2519	1,46900576	1609,4887	1,57806022	1705,749	1,77881225	1922,7448	1,97867879	2138,7836	2290,0107	1080,915	3786,55656	8,91177094	
	2818	3786,55656	13,2316554	3125,8828	3294,86	1,6921929	3294,86	1,6921929	3660,9555	1,46900576	4196,0182	1,57806022	4446,9737	1,77881225	5012,6329	1,97867879	5575,9168	5970,1736	2818	3786,55656	13,2316554	
	2818	4470,75413	18,8424565	6009,18	6966,433	1,6921929	6966,433	1,6921929	7740,4811	1,46900576	8871,7822	1,57806022	9402,3858	1,77881225	10598,505	1,97867879	11789,348	12622,938	4183,995	5082,63918	18,8424565	
	4183,995	5082,64237	23,5001312	8242,906	8688,4685	1,6921929	8688,4685	1,6921929	9653,8539	1,46900576	11064,802	1,57806022	11726,565	1,77881225	13218,354	1,97867879	14703,562	15743,208	5958,192	5465,08617	23,5001312	
	5958	5465,08617	26,1723975	9180,2302	9676,4588	1,6921929	9676,4588	1,6921929	10751,621	1,46900576	12323,012	1,57806022	13060,026	1,77881225	14721,45	1,97867879	16375,546	17533,413	7431	5465,08617	26,1723975	
	7431	5651,52422	30,5580767	10718,551	11297,932	1,6921929	11297,932	1,6921929	12553,258	1,46900576	14387,965	1,57806022	15248,48	1,77881225	17188,307	1,97867879	19119,577	20471,467	8276	5651,52422	30,5580767	
	8276	5919,7123	30,5580767																20471,467	5919,7123	30,5580767	
	9662,8																			9662,8		

Figure 2.65. A table of frequencies for the nine scale steps used for the diamond theme.

Hearts

The theme of hearts was based on a rhythm constructed of sounds from a cement mixer. The idea was that the rhythm would be steady when the theme was presented for the first time. Towards the end of the piece the rhythm would be altered, as the theme of spades would begin to dominate the mix. The inspiration for the rhythmic theme came from the sketch of hearts made by Hansson (see Figure 2.67).

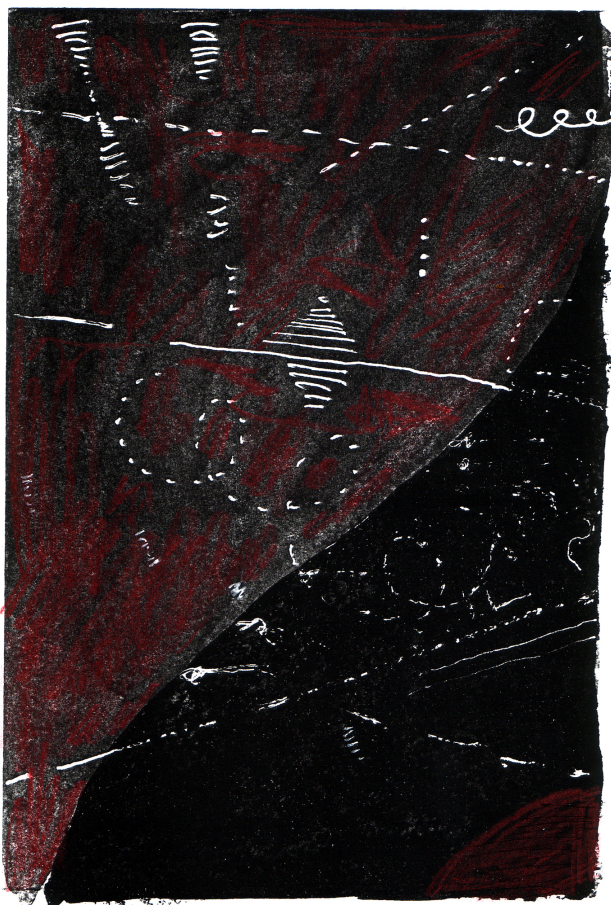


Figure 2.67. A sketch for the theme of hearts.

The sound used to construct the rhythm was not the sound that the scale of hearts was built upon. The scale for hearts was not constructed with a dissonance curve as for this theme I chose a different method to build a scale - still with spectrum in mind. I wanted to include a different application of non-harmonic concrete sounds to govern the musical structure in order to have more choices concerning the harmonic progression throughout the piece.

I analysed nine different sounds from the same sound source - a recording of the spokes from a bicycle turned upside down. From this analysis I chose five different sounds that had some

similarities in spectra, one being that the three first partials in each spectrum were an octaves apart (see Figure 2.68).

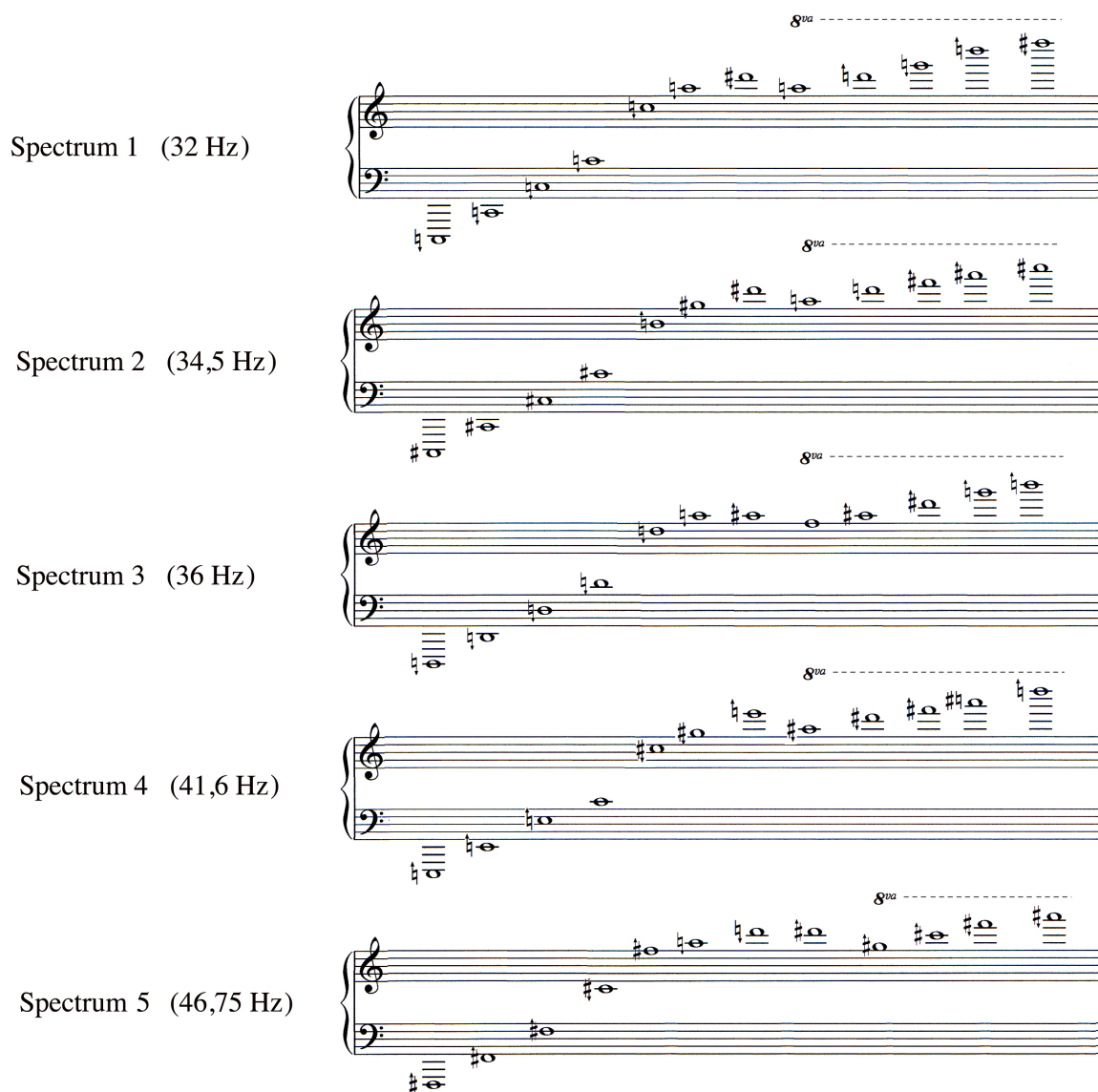


Figure 2.68. A note transcription of the five bicycle sound spectrum.

The five sounds had different fundamental frequencies and these frequencies were the base for the scale as seen in Figure 2.68 and Figure 2.69. Sound Example 17-21 portrays the five scale steps mapped onto the cement mixer rhythm.

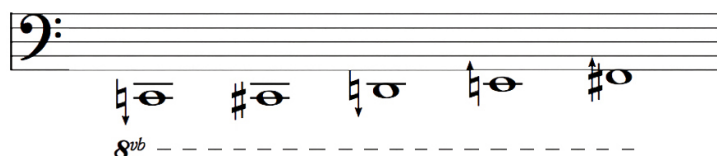


Figure 2.69. The five scale steps for the theme of hearts.

A list of all the spectra of each scale step are included in Appendix 11.

Spades

For spades, intended to convey an impression of power and dominance, I chose to use a spectrum based on 2:1 octaves only throughout the audible frequency range. As music based upon the harmonic spectrum has been dominating western music for centuries I thought it appropriate that octaves from this spectrum would portray spades.

Two fundamentals were used for this purpose: one based on 22.5 Hz and another on 33 Hz as the sound material chosen for spades contained these two frequencies. The interval between these two fundamentals equals approximately 537 cent \approx a stretched fourth. The sound portraying spades was originally a recording mistake, a thump caused by hitting the microphone. The sketches in Figure 2.70 inspired me to use material with low bass and high frequencies for the theme of spades and I used more “recording mistakes” that I could find in recordings made for diamonds and hearts. These sounds were filtered to fit the two harmonic spectra and then processed with high and low pass filters.

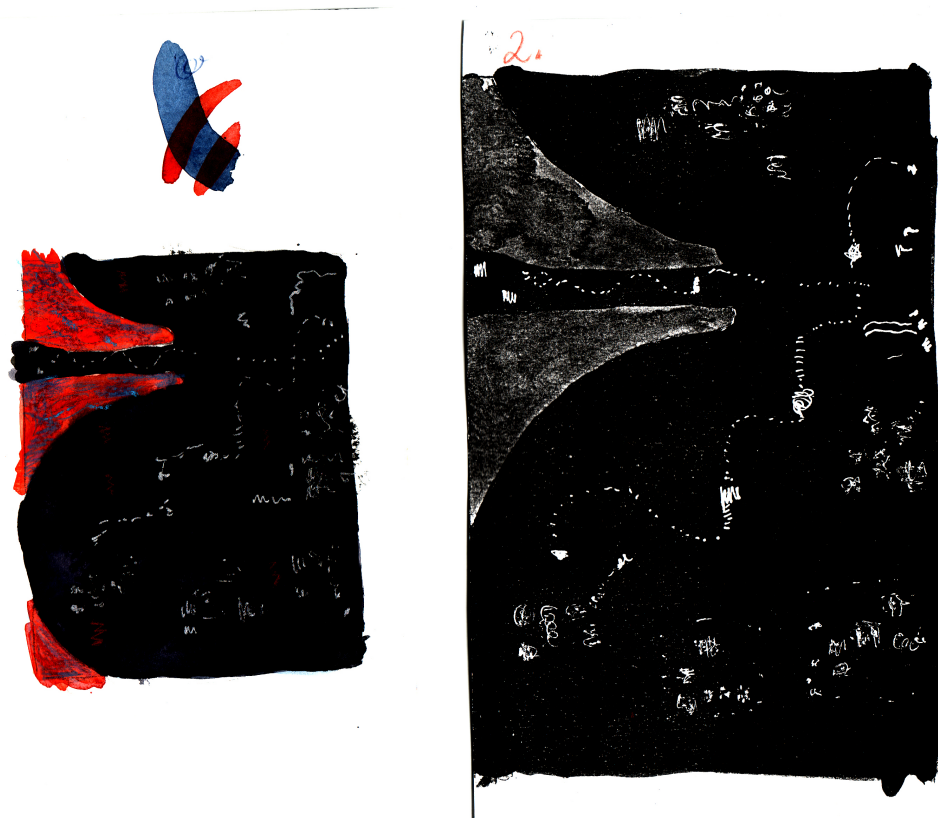


Figure 2.70. A sketch for the theme of spades.

The overall form

The concept governing the overall form of the work was that each of the four themes (clubs, diamonds, hearts and spades) would come to the fore once throughout the piece. The symbols for each theme filled with colour in Figure 2.71 signify these instances. For example, the clubs theme would begin the piece and then be heard in processed forms whereas the theme of spades would not reveal itself in until towards the end. There would be a connection between the mobile light and the overall form. For example, in the beginning of the piece the clubs textile would be lit and when diamond material at 1'30 would be heard, the light would focus on the diamond shapes in the clubs' textile (see small red diamond shape in the middle of Figure 2.60 on the sketch for clubs). All four textiles contained details of each of the four themes, something that would be accentuated by the light.

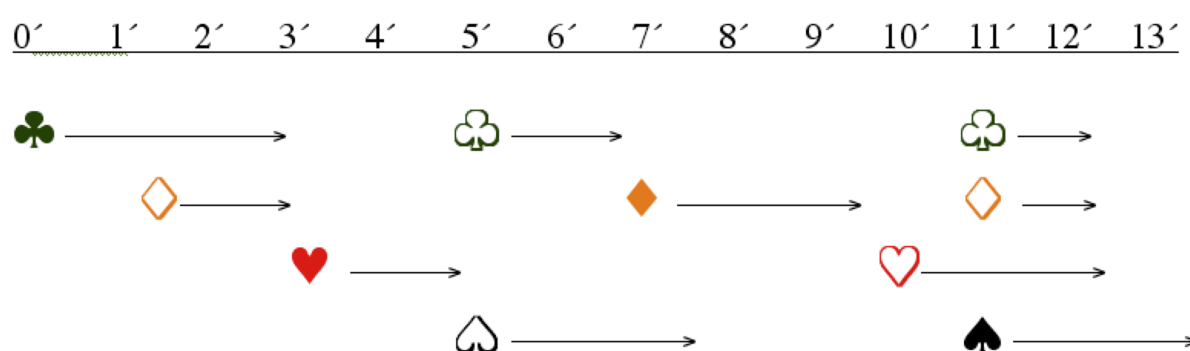


Figure 2.71. The overall form of how the different themes would be used during the piece.

The timings of the events were originally based on the Fibonacci series⁹⁴ as a time-grid. However, when I had created the first visual time-grid I thought that the events would be too far apart during the second half of the piece and I used prime numbers instead. This new overall form struck me as being too static as most events would be exactly two minutes apart. In the end I decided not to have a rigid construction based on number series and alterations of the second overall form as shown in Figure 2.71 were based on intuition imagining the pace of the light following each textile.

⁹⁴ A sequence of numbers in which each is the sum of the previous two, thus: 0, 1, 1, 2, 3, 5, 8, 13, 21, 34 etc. Tatlow, R., *Grove Music Online*, Oxford University Press, (2007-2010). Accessed 7 August 2010.

Processing the sound material

For *Joker* I modified and expanded the sound processing tools that I had created for *Utresa* (see Figure 2.72). A lot of material in *Joker* was based on transforming sound material from one spectrum to another, i.e. from the spade spectrum to the diamond spectrum including all its transpositions. With these tools I could modulate between different spectra with full control of the frequencies involved.

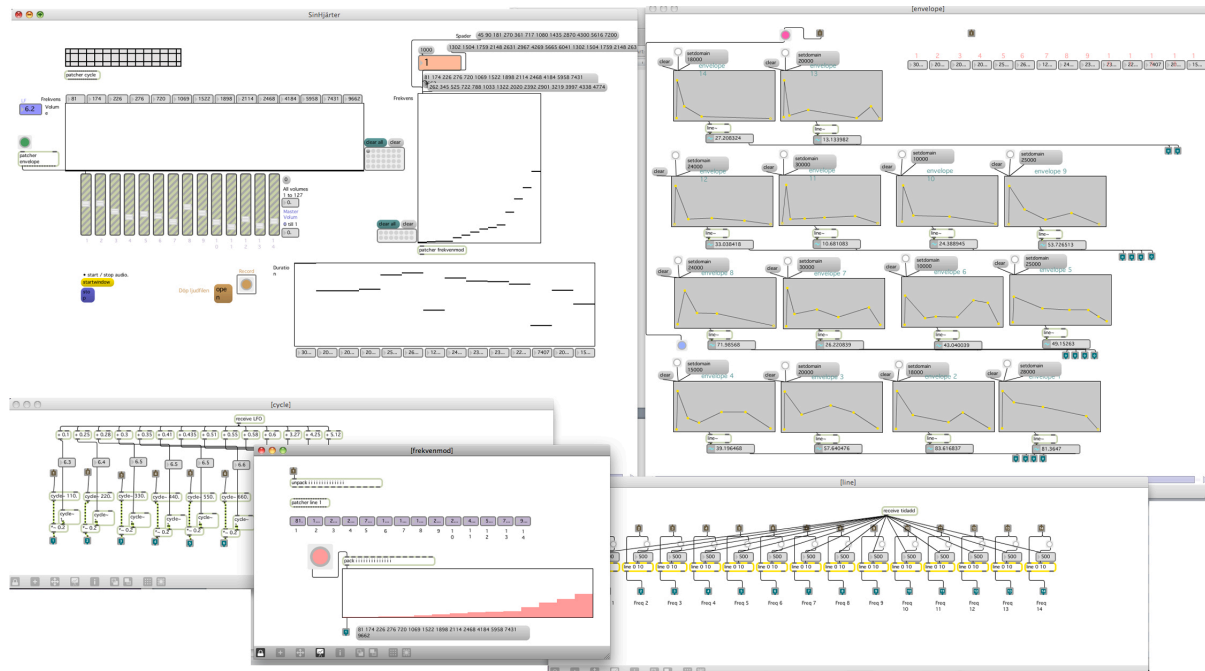


Figure 2.72 A new additive synthesis patch built in Max/MSP for *Joker*.

The following sound examples are included to illustrate how I processed sounds in *Joker*. One technique was to modulate from one spectrum to another through filtering where the interpolation time could be varied. Sound example 22 is an example of a transition from a diamond spectrum to a spade spectrum. Another technique was to map a sound spectrum from one theme onto the sound that was used to illustrate another theme. Sound example 23 is an example of a diamond spectrum transposition (1×1.49) mapped onto a hearts theme (the rhythmic cement mixer). A third technique was to use neutral sounds that did not belong to any theme and map the respective theme spectra onto these sounds. A fourth technique was to create new sounds with additive synthesis for each spectrum in order to portray all the themes with a neutral synthesis sound (Sound example 24-30). With these techniques I was able to work with modulation and transitions in different ways.

Multi-channel version

As with *Clandestine Parts* and *Utresa*, the multi-channel mix was planned from the stereo version. Each separate stereo sound file was given a placement in a speaker configuration according to Figure 2.73.

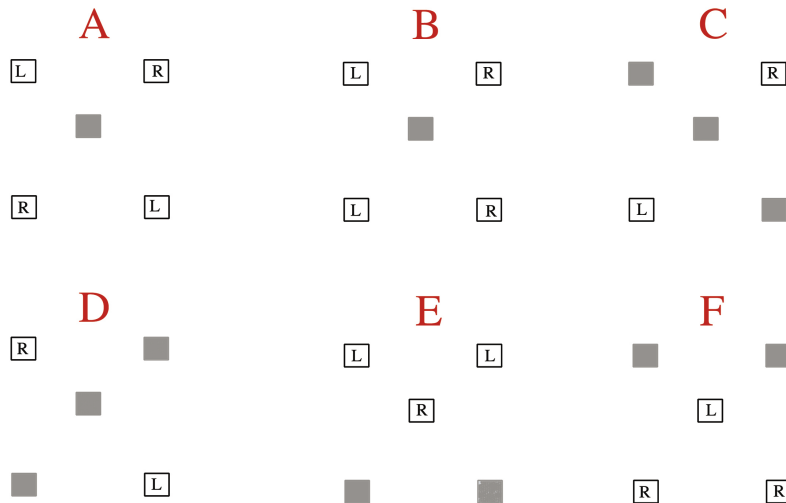


Figure 2.73. Six different loudspeaker configurations.

A similar mixing method to *Clandestine Parts* and *Utresa* was used with the difference that *Joker* was mixed to 5.1-format with four loudspeakers in a square and a centre speaker in the ceiling (the centre speaker in the middle). The bass speaker content was constructed by filtering the bass from the stereo version. The idea of the centre speaker in the ceiling was adapted for the premises of the Textile Museum where the audience sat in a dark room on a bench facing the textiles (see Figure 2.74) surrounded by the 5.1-system.

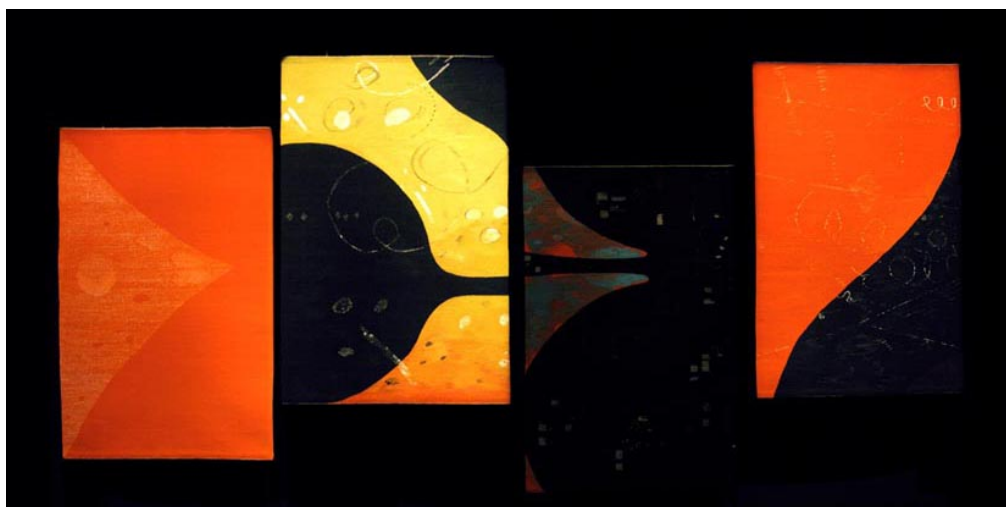


Figure 2.74. The textile series *Joker* from an audience perspective at the Textile Museum.

Evaluation

My conclusion was that combining four sets of harmonies in a piece worked satisfactory and as an installation piece the overall form worked well. I found working with a number of harmonic sets within the same piece inspiring as I could modulate not only within one set of scales and its transpositions but also modulate between several different sets of scales and transpositions. In this manner I could work with progression harmonically rather than static (as in *Utres* where only one spectrum was used to determine the scales). However, with the tools at my disposal at the time, the task was indeed time-consuming.

In *Utres* and in *Joker* I had composed pieces that were combined with a visual media, the textiles. In my next piece I wanted to explore harmony based on the research made by Sethares with a fixed media piece without visual media.

2.9 The Ringing stone of Håga (2006)

- fixed media in stereo and 5-channel: 7'40

The Ringing Stone of Håga was commissioned by Swedish National Radio P2 in 2005. The title was based on a “ringing stone” just outside of Uppsala in Sweden, a stone that according to archaeologist Helena Victor proposed may have used for ritual ceremonies during the bronze age⁹⁵ (see Figure 2.75). If a person struck the ringing stone with another smaller stone a resonant tone could be heard. Over many years use the ringing stone has developed indentations and hollows, each with a particular sound character when struck.

⁹⁵ Victor, H., ‘The grave as a Neighbour. On Bronze Age Ritual Houses’, *Aun* 30, Uppsala University, The Department of Archaeology and Ancient History, (2002), pp. 175-176.



Figure 2.75. The ringing stone in Håga, Uppsala.

Concept and method

In *The Ringing Stone of Håga* I wanted to return to the idea explored in *Ti Chor* regarding the creation of melodies from a spectrum and now combine this with scales based on Sethare's dissonance curves.

After extensive work in *Joker* using four spectra I wanted to use merely one spectrum. The idea for *The Ringing Stone of Håga* was to use one of the sound spectra of the struck indentations from the ringing stone.

Compositional process

In this piece there were certain parameters determined in advance such as using the ringing stone spectrum as a musical structure (M) that would control the harmony (H). I allowed the structuring of the material in time (T) to be changed throughout the compositional process as seen in Figure 2.76.

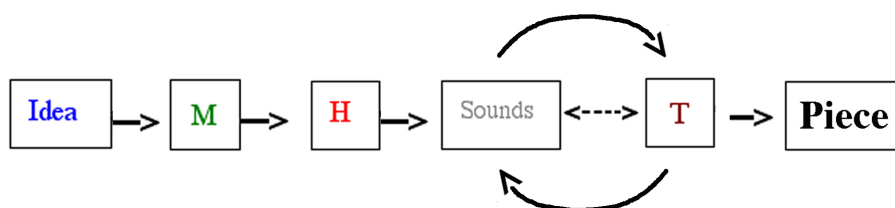


Figure 2.76. A model of the compositional process of *The Ringing Stone of Håga*.

The process of choosing sound

The idea of using the ringing stone in Håga came from reading about it in a fictional novel. I did some research and found out that the stone actually existed and managed to find out where it was. As it was winter at the time, the stone could not be moved and was recorded as it lay. Different parts of the stone caused different resonances. The areas that were struck were marked with colour post-it notes as seen in Figure 2.75.

I performed a spectrum analysis of the different sounds and chose one that I believed had the most interesting spectrum (see Figure 2.77, Sound example 31).

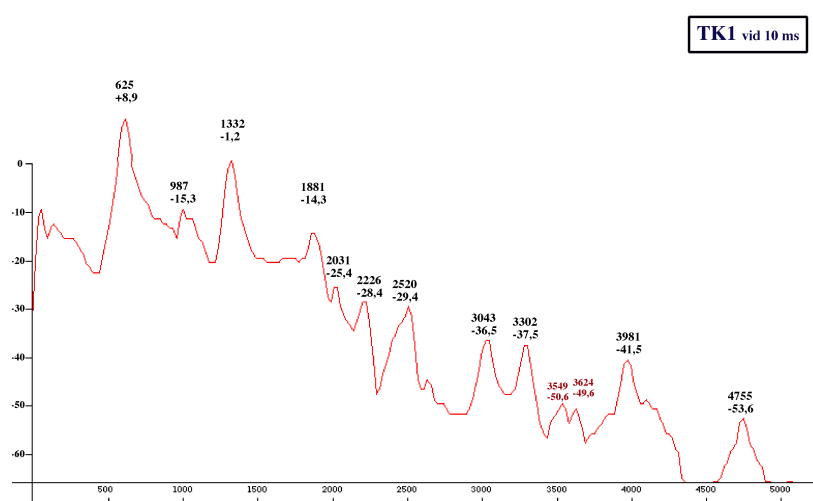


Figure 2.77. The spectrum of the chosen ringing stone sound. The x-axis: frequency in Hertz, the y-axis: amplitude in Decibel.

Creating a scale

Based on a comparison between several analyses I chose twelve partials from the sound which were used in the calculation of the dissonance curve (see Figure 2.78).

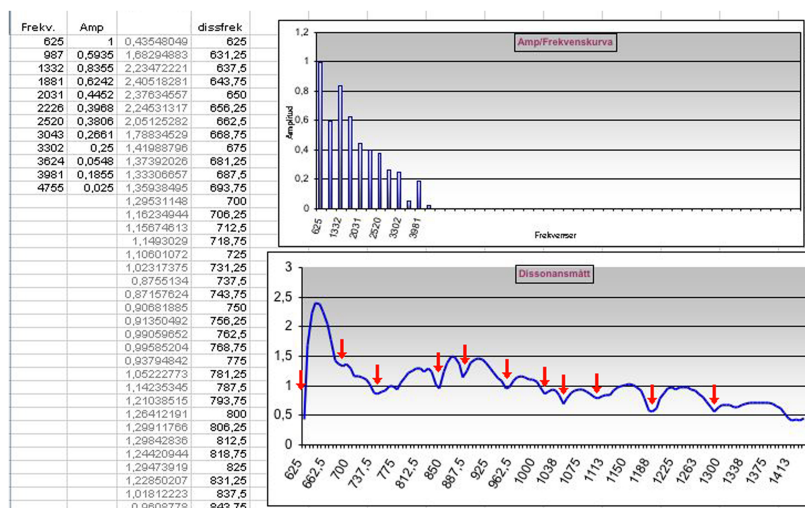


Figure 2.78. The dissonance curve based on the ringing stone sound.

From the dissonance curve I chose the scale steps as seen in Figure 2.79.



Figure 2.79. A note transcription of the scale steps derived from the dissonance curve.

A tool in Max/MSP was then developed in order to compare the spectra of the scale steps with different transpositions (see Figure 2.80).

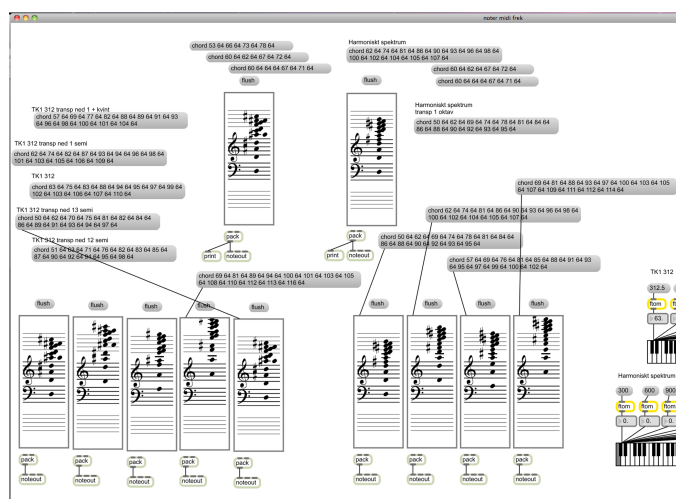


Figure 2.80. A transposition tool in Max/MSP.

As in the two previous pieces a table of frequencies for the scale steps was calculated (see Figure 2.81).

Petroleum Transportation	Fuel		Fictitious		Fictitious		Fictitious		Fictitious		Fictitious		Fictitious		Fictitious		Fictitious		Fictitious		Fictitious		Fictitious		Fictitious		Fictitious		Fictitious		Fictitious	
	Fictitious	Cost	Index	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	Fictitious	
	625	790,970,421	1,5792	1.1	687.5	1.13	706.25	1.19	743.75	1.35	843.75	1.41	881.25	2,3409	1463,0625	1.62	1017.5	1.67	1043.75	1.76	1100	625,000	790,970,421	1,5792	164,991,331	164,991,243	625	1187.5	2.06	1287.5	Fictitious	
	987	1309,89609	2,1312	1086.7	1086.7	1115.31	1174.53	1174.53	1332.45	1332.45	1332.45	1332.45	1391.67		2310,4683		1398.94	1398.94	1648.29	1731.12	987	510,929,696	1309,89609	2,1312	46,594,926	211,570,676	887.5	1875.3		2033.22	Fictitious	
	1332			1465.2	1465.2	1535.16	1585.08	1585.08	1798.2	1798.2	1798.2	1798.2	1878.12		3118,0788		2157.84	2224.44	2244.32	2344.32	1332	597,499,899	1307,33599	3,0096	88,599,929	301,130,188	706.25	2330.8		2743.92	Fictitious	
	1881			2069.1	2069.1	2125.53	2238.39	2238.39	2539.35	2539.35	2539.35	2539.35	2632.21		4402,2329		3047.22	3141.27	3141.27	3310.56	1881		1307,33599	3,0096	10,599,929	301,130,188	743.75	3573.9		3874.06	Fictitious	
	2881			2234.1	2234.1	2295.03	2416.89	2416.89	2741.85	2741.85	2741.85	2741.85	2883.71		4754,3679		3286.22	3391.77	3391.77	3574.58	2881		2040,15401	3,2496	218,380,131	518,510,401	943.75	3888.9		4183.06	Fictitious	
	2226			2446.6	2446.6	2513.38	2646.94	2646.94	3005.1	3005.1	3005.1	3005.1	3138.66		5210,8494		3606.12	3717.42	3717.42	3917.76	2226		2198,85754	3,5616	53,969,902	594,787,383	1,41	4229.4		4585.56	Fictitious	
	2520			2772	2772	2847.6	2968.8	2968.8	3402	3402	3402	3402	3553.2		5889,068		4082.4	4208.4	4208.4	4465.2	2520		2413,60481	4,032	87,570,904	1472,9609	2,409	4788		5191.2	Fictitious	
	3043			3347.3	3347.3	3438.59	3621.17	3621.17	4108.05	4108.05	4108.05	4108.05	4290.03		7123,3397		4929.66	5081.81	5081.81	5355.68	3043		2740,05383	4,8888	487,252,330	835,12848	1,62	5781.7		6268.59	Fictitious	
	3302			3632.2	3632.2	3731.26	3903.38	3903.38	4467.7	4467.7	4467.7	4467.7	4655.82		7728,6518		5349.24	5514.34	5514.34	5811.52	3302		2881,46765	5,2832	534,006,901	887,747854	1,67	6273.8		6802.12	Fictitious	
	3624			3986.4	3986.4	4085.12	4312.56	4312.56	4882.4	4882.4	4882.4	4882.4	5109.84		8483,4216		5970.88	6052.08	6052.08	6328.24	3624		3042,54637	5,7994	908,629,991	978,613484	1,76	6885.6		7465.44	Fictitious	
	3881			4378.1	4378.1	4498.53	4737.29	4737.29	5374.35	5374.35	5374.35	5374.35	5613.21		9113,1229		6449.22	6648.27	6648.27	7005.56	3881		3205,19107	6,3696	102,489,936	1111,1185	1,9	7563.9		8200.06	Fictitious	
	4735			5230.5	5230.5	5373.15	5693.45	5693.45	6419.25	6419.25	6419.25	6419.25	6704.15		11130,9795		7705.1	7940.85	7940.85	8388.8	4735		3512,74423	7,698	139,630,579	1251,0274	2,06	9094.5		9795.3	Fictitious	

Figure 2.81. Table of frequencies for the scale steps and their spectrums.

How the sound was used

The original sound of the ringing stone can be heard at certain points throughout the whole piece. The melody, which weaves its way through the piece like a thread, was constructed from the actual spectrum. For example, Figure 2.82 displays the mix from the opening melody of the piece, which was created using sine tones mixed in ProTools (Sound example 32). Some partials were magnified, others extended in time. The melody was altered throughout the piece dependent on the harmonic progression.

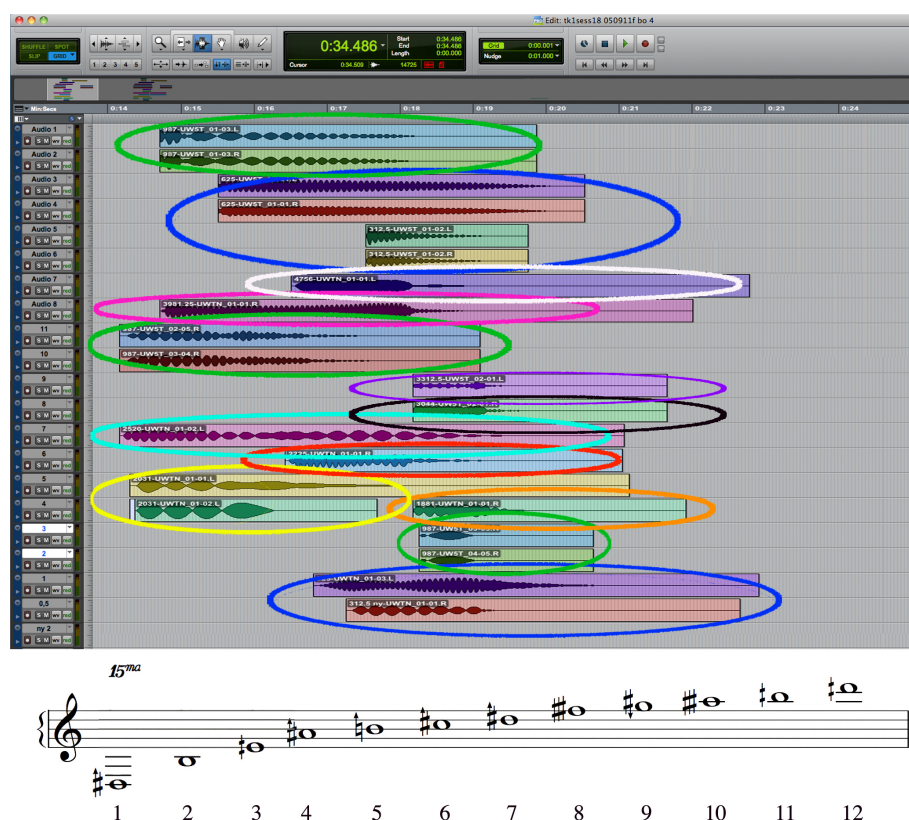


Figure 2.82. A melody based on the spectrum of twelve partials.

The partials used for the opening melody are marked in Figure 2.82 with the following colours:

Partial 1 + octave down:	Dark blue	625+312,5 Hz
Partial 2:	Green	987 Hz
Partial 4:	Orange	1881 Hz
Partial 5:	Yellow	2031 Hz
Partial 6:	Red	2226 Hz
Partial 7:	Light blue	2520 Hz
Partial 8:	Black	3044 Hz
Partial 9:	Purple	3312 Hz
Partial 11:	Pink	3981 Hz
Partial 12:	White	4755 Hz

A sonogram of Sound example 32 clearly shows how the building blocks of the melody consist of pure sine tones (see Figure 2.83).

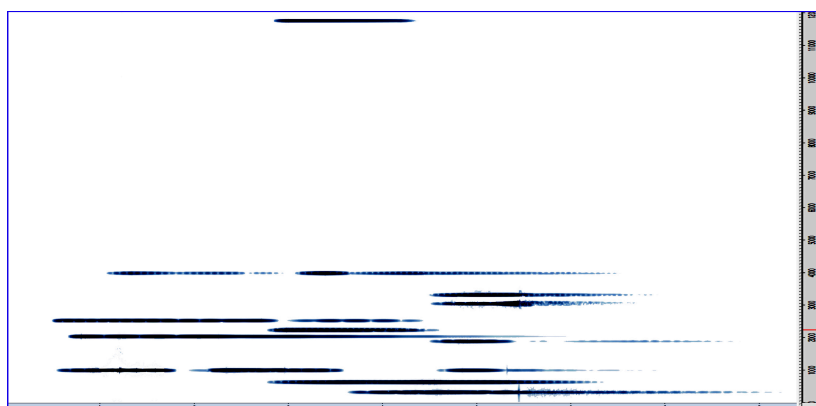


Figure 2.83. A sonogram of the melody up to 12 kHz.

At 2'05 a theme based on the actual sound of the ringing stone (Sound example 33) is presented. *The Ringing Stone of Håga* was built upon this theme and the sine tone melody. The piece was then intuitively constructed from these materials.

Multi-channel version

As with the other multi-channel works in the portfolio, the multi-channel mix was planned from the stereo version. Each separate stereo sound file was given a placement in a speaker configuration according to Figure 2.84.

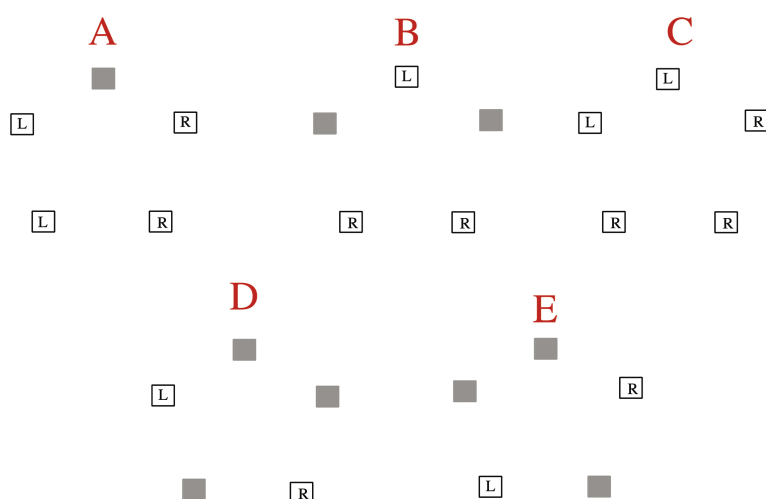


Figure 2.84. Five different loudspeaker configurations.

The mixing method was similar to that of *Utresa* and *Joker* but with a different loudspeaker configuration.

Evaluation

The Ringing Stone of Håga was the third piece in which I have explored harmonic relationships based on the research made by Sethares. Even though the compositional results were successful I needed other tools in order to explore this path further as the working process was too time-consuming. For this reason, I initiated a project at the Royal College of Music in Stockholm developing tools in Max/MSP-environment with the Swedish composer and Max/MSP-programmer Sten-Olof Hellström. The idea was to create tools that would make the process of analysing sounds, creating a dissonance curve and calculating scales more efficient and quicker.

Whilst working on this project with Hellström I explored other compositional paths writing two pieces for instruments.

2.10 *Taal Bundu* (2009)

- saxophone quartet (soprano, alto, tenor, baritone) and fixed media: 9'15

Taal Bundu is a piece for saxophone quartet and fixed media, commissioned by the Swedish National Concert Institute (Rikskonserter) to be performed by the Stockholm Saxophone Quartet. The piece was begun in 2006 and the first version of the piece had its premiere in Stockholm in October 2009. The composition has since then been revised and the final version was completed in September 2010.

Concept and method

In this piece, the rhythmic element is stronger than in other works in this portfolio. The concept for the piece was to use the saxophones as a meta- percussion instrument. My main inspiration came from hearing the Birmingham based tabla player Sarvar Sabri playing to a melody (lehra) in a classical Indian 17/8 rhythm, *Taal Bundu Khani*⁹⁶. The melody composed by Sarvar Sabri and the harmonium player Pandit Vishwa Prakash is present and repeated throughout the whole piece. By using the same melody and working with the saxophones as rhythmical instruments, I wanted to create my own interpretation of the original Indian piece.

⁹⁶ *Taal Bundu Khani*, a classical Indian rhythm with a unusual time cycle of 8 1/2 beats divided into 3+3+2+1/2.

Compositional process

Throughout the whole piece the melody from *Taal Bundu Khani* in 17/8 rhythm (see Figure 2.85), was used as a foundation for the compositional process (see Figure 2.86) like a *Cantus Firmus*.



Figure 2.85. The melody from *Taal Bundu Khani* that was used in *Taal Bundu* with permission from Sarvar Sabri and Pandit Vishwa Prakash.

All sound material in the piece was composed to accompany the melody that was used as an audible time-grid as well as a pitch-grid. The idea behind using the melody as an audible time-grid was based on practicality: the saxophonists would be able to rehearse the piece listening to the melody in the fixed media part, an idea that was later abandoned in favour of a more musical result.

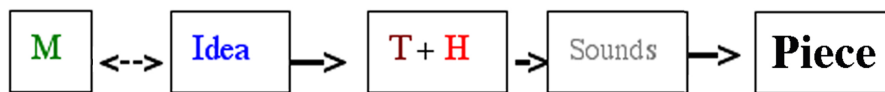


Figure 2.86. The compositional process of *Taal Bundu*. The Musical structure (M) was based on the melody that was used like an underlying grid throughout the piece (T). The melody was used as a foundation for the harmony (H) and the pitch content in the sound material.

The sounds used, consist mostly of extended playing technique sounds made by the Swedish saxophonist Jörgen Pettersson. The sounds were short and percussive, from spoken sounds to playing without the mouthpiece. These sounds were recorded, categorised and used in the fixed media part.

Sounds from an accordion were also recorded and used in the fixed media part. The Swedish composer and musician Catharina Backman played the melody and specific chords, material that later was edited in software plug-ins such as GRM-tools in ProTools. The chord material was based on fifths, for example an F and a C played together.

The musical structure and its effect on the time-domain, harmony and sound material

The musical structure throughout the piece was based on rhythmical variations of the melody with the intention of avoiding repetition. The intention was that every bar would have its unique character. The repeated melody (Cantus Firmus) would also vary in timbre.

The piece is divided into two sections. The first part consists of extended playing technique sounds with the mouthpiece off, in both the saxophone part and the fixed media part. A lot of consideration was put in notating the extended playing technique sounds so that they would produce a specific pitch (see Figure 2.87).

The melody is not clearly audible until three and a half minutes into the piece. It then remains present throughout the whole composition in various forms. In the second part the saxophones play pitched material with the mouthpiece on. The melody is present in the fixed media part and the saxophones together form a rhythmical accompaniment in a hocket, a technique used in the first part as well but with the extended playing techniques (see Figure 2.87).

Taal Bundu

The image displays a musical score for a piece titled "Taal Bundu". It consists of two systems of staves, each with four staves (treble and bass clef). The notation is highly detailed, featuring numerous accidentals, dynamic markings (e.g., *f*, *ff*, *mf*), and specific performance instructions in italics such as "foul", "full", "rt", "kl", "te", "ti", "to", "eh", "k", "e", "a", "t", "rt", "te", "kl", "t", "rt", "te", "kl", "t", "rt", "te", "kl", "t". Above the staves, there are handwritten notes and symbols, including "foul", "Sho", "f", "te", "f", "te", "t". The score is divided into measures, with measure numbers 9, 10, 11, 12, 13, 14, 15, and 16 visible. The notation is complex, with many notes and rests, and a focus on specific timbral effects through extended playing techniques.

Figure 2.87. Page 2 from the score in C. The extended playing techniques in the saxophone part are specified in detail regarding pitch content and what technique to use. Even though the sounds produced are shorter than notated in the score, this way of notation was in favour of visibility. The audible effect is that of a hocket.

The harmony of the piece was determined by the pitch content in the original melody transposed one half step up and also from the analysis of a tabla playing with different techniques. I listened through different recordings of classical Indian music with tabla, analysed the pitches the different playing techniques produced in relation to the scales used in each recording, and then added these pitches to those of the melody in order to be the foundation for the pitch material used in *Taal Bundu*.

The sounds from the saxophone instruments played without a mouthpiece had a specific resonant pitch, a pitch depending on the actual body of the instrument that could not be altered. The melody was transposed in order to work with these pitches and this determined the key for the composition (see Figure 2.88).

Performance

The score was notated with a tempo of crotchet = 50 with one of the saxophonists using a click track to conduct the other three musicians during the performance.

The notation of the melody in 17/8 was divided into one bar in 4/4 followed by one in 9/8 (see Figure 2.88).



Figure 2.88. The melody from *Taal Bundu Khani* was transposed in order to work with the built in resonance pitch of the saxophone instruments.

There were over twenty different extended techniques used, each specified in the instruction leaflet (see Appendix 17, page 2).

Evaluation

Taal Bundu is the first piece where I have worked consciously with rhythm as the most important musical parameter. It is also the first time where I have worked with repetition as way of structuring the overall form.

There is a similarity with the earlier piece *Ti Chor* in the sense that the instrumental and the fixed media part were composed with similar sounds in order to create a perceptual ambiguity during performance.

In *Taal Bundu* I worked with pitch in a different way than in the previous three pieces. I edited sounds so that they would work with traditional western harmony and focused on rhythm in order to develop my knowledge of a traditional musical parameter that had played only a small part in my previous work.

After *Taal Bundu* I wanted to return to the path of exploring harmonic concepts other than traditional western harmony, this time with a purely instrumental composition, and see if I could combine the spectral work made in *Ti Chor* with string instruments.

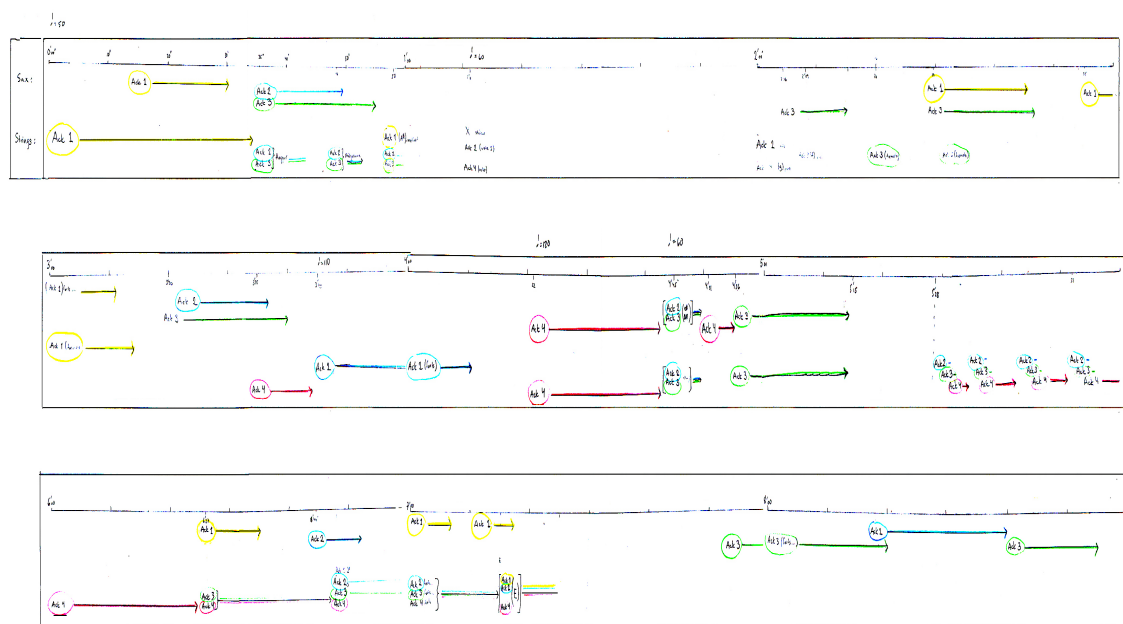
2.11 *Ytspänning* (2010)

- string orchestra (9 violins, 3 violas, 2 violoncellos, 1 double bass) and saxophone quartet (soprano, alto, tenor, baritone): 10'00

Ytspänning is a piece for string orchestra and saxophone quartet, commissioned by CoMA (Contemporary Music and Artists) and Musik i Väst in Sweden. The composition completed in January 2010 will have its premiere in Sweden in May 2011 performed by the Växjö-based string orchestra Musica Vitae and the Stockholm Saxophone Quartet.

Concept and method

The main concept for the piece was to create pitch material extracted from the spectrum of four different multiphonics played by the saxophones. Modulations would then be made between these different multiphonics throughout the composition according to Figure 2.89 (see also Appendix 12).



Ack 1 = soprano multiphonic no. 1

Ack 3 = alto multiphonic

Ack 2 = soprano multiphonic no. 2

Ack 4 = baritone multiphonic

Figure 2.89. An overall form for modulations based on the four multiphonics through time. The saxophone modulations are shown in the top layer within the frame and the modulations for the strings in the bottom layer.

The idea behind the overall form was that the material towards the end of the piece would be based on a different spectrum than the beginning. The middle section would contain one single spectrum introduced later in the piece, and towards the climax all four spectra would be present. The piece would end with the strings playing harmonics on D - the pitch that all four spectra have in common (see Figure 2.90).

The analysis of the four multiphonic spectra had already been made as I had analysed a number of multiphonics for the earlier work *Ti Chor*. Three of the four multiphonics had been used in *Ti Chor* and in *Ytspänning* I wanted to introduce a new baritone multiphonic in order to complement the pitch material that could be derived from the spectra (see Figure 2.90 and 2.91).



Figure 2.90. The chosen partials from the spectrum of the four multiphonics used in *Ytspänning*.

I chose not to use a vast number of partials of each spectrum as I wanted to concentrate on the partials that were strongest in amplitude and that therefore would be audible as separate pitches. I wanted the relationship between the saxophone multiphonics and the material derived from the spectra to be perceivable. The pitch material derived for each spectrum was translated into the traditional western twelve-tone scale as shown in Figure 2.91.



Figure 2.91. The pitch material derived from each spectrum translated into 12^{tet} scale. The circles mark pitches that are unique for each particular spectrum, i.e. the pitch A# is strong only in the soprano multiphonic no. 1.

Compositional process

When the first draft of the score was completed, I revised it and came up with alternative ideas that I then tried out resulting in a new draft. Changes were made to the overall form as the compositional process progressed (see Figure 2.92).

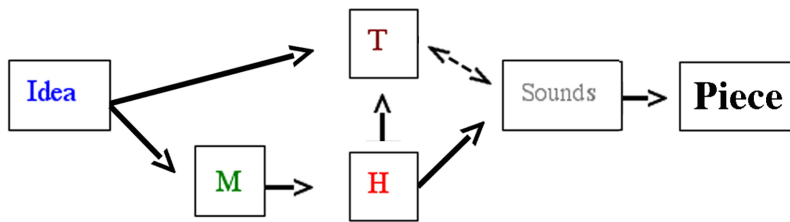


Figure 2.92. The idea for *Ytspänning* was to use four saxophone multiphonics as a musical structure that would determine the harmony and pitch material. As the piece progressed the time-structure was altered depending on the material.

The musical structure and its effect on the sound material

The piece begins with sound material based on the soprano multiphonic no. 1 (see Figure 2.89 and 2.90). The tonal centre evolves around the note E, the strongest resonating frequency in the analysed multiphonic. A majority of the strings then play the spectrum in pizzicato at different speeds. The few notes that differ from the spectrum are used to accentuate the pitches from the spectrum and are usually within a narrow interval, a minor second to a third (see Figure 2.93).

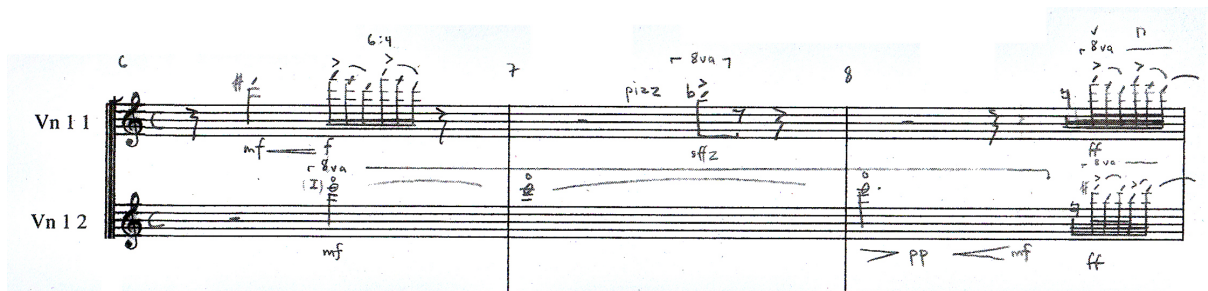


Figure 2.93. In bar 6 and 8 the first violins play a small motif containing pitches that do not exist in the spectrum from soprano multiphonic no. 1. The motif is used to accentuate the pitches E and D# from the spectrum.

In bar 9 the soprano multiphonic no. 2 and alto multiphonic are introduced (see Figure 2.89 and 2.90) and the pitch material in the string part move towards these spectra (see Figure 2.94).

3
2/4

Handwritten musical score for Figure 2.94, showing vocal and instrumental parts from bar 9 to 12. The score includes staves for Soprano (S), Alto (A), Tenor (T), Baritone (Bar), Violins 1-5 (Vn 1-5), Violas 1-3 (Va 1-3), Violoncello 1 (Vcl 1), Violoncello 2 (Vcl 2), and Contrabass (Cb). The vocal parts have lyrics in German. The instrumental parts show various musical notations including dynamics (p, mp, mf, f, pp, ff), articulation (pizz, arco), and performance instructions. The score illustrates a gradual change in pitch content for the string material as the vocal parts are introduced and altered.

Figure 2.94. The string material gradually changes pitch content as the soprano multiphonic no. 2 and alto multiphonic are introduced in bar 9. In bar 12 most of the material has been altered.

A different way of using the spectrum can be seen in bar 106 and onwards. In bar 93 to 107 three of the spectra have been presented with a short arpeggio melody for each spectrum as seen in Figure 2.95.

The image displays a musical score for measures 106 and 107. The instruments listed on the left are Vn 1 1, Vn 1 2, Vn 1 3, Vn 1 4, Vn 1 5, Vn 2 1, Vn 2 2, Vn 2 3, Vn 2 4, Va 1, Va 2, Va 3, Vcl 1, Vcl 2, and Cb. The score is divided into two measures, 106 and 107, with a double bar line in between. Above measure 106 is a bracket labeled (I) and above measure 107 is a bracket labeled (II). The notation includes various musical symbols such as notes, rests, and dynamic markings like (p), (mp), and (mf). Some instruments have specific performance instructions like 'arco' or 'pizz'. The Vcl 1 part in measure 107 is marked '(solo)' and 'arco'. The Cb part is mostly silent in both measures.

Figure 2.95. Arpeggio melodies based on three different spectra.

In bar 107 a solo melody in the cello was constructed based on free use of the pitch content of the forth (baritone) spectrum with accompanying strings based on the same spectrum (see Figure 2.95 and 2.96).

Evaluation

Ytspänning has certain compositional aspects in common with the earlier piece *Ti Chor*. In both pieces the musical structure is based on spectrum analysis of saxophone multiphonics. They also have in common that melodies have been structured based on the spectra. In *Ti Chor* the melodies appeared one after another and modulations were made between the melodies. In *Ytspänning* the melodic material extracted from the spectra at times was allowed to occur simultaneously. In this way a new timbre based on more than one spectrum at a time was created.

Most material in the saxophone parts in both pieces consists of extended playing techniques such as multiphonics and noise sounds. In *Ytspänning* the variety of extended playing techniques is greater as I learned more about these making the previous piece *Taal Bundu*. After working with *Taal Bundu* I also felt more confident in working with rhythmical structures, which I in *Ytspänning* combined with spectral elements.

The way I composed the string part for the first half of the piece is similar to the way I compose for fixed media, for instance using the individual string musicians to build a texture similar to the additive synthesis in *Ti Chor*. The short motifs seen in Figure 2.93 I treated as gestural elements as I did with the short sounds in *Med lekande Kval*. The second half of the composition *Ytspänning* is more based on traditional composition techniques with melodic lines and elements of counterpoint, the latter, to a certain degree, is present in other works such as *Taal Bundu* (the accordion melody in the last minute of the fixed media part) and the *Ringling Stone of Håga* (at 2'04).

When *Ytspänning* was completed I wanted to return to composing with instruments in combination with fixed media. The idea was to close the circle and to combine the knowledge I had gained in psychoacoustics to see if there was a way to include instruments in this way of working.

2.12 *Echo in Silence* (2010)

- percussion, trombone and fixed media: 8'00

Echo in Silence is a piece for percussion, trombone and fixed media, commissioned by CoMA and Musik i Väst in Sweden. The composition was premiered in September 2010 by the Swedish percussionist Jonny Axelsson and trombonist Ivo Nilsson.

Concept and method

The main concept for this piece was to merge different techniques I had explored in previous works.

As in *Ti Chor*, one of the concepts for *Echo in Silence* was to integrate closely the spectral content of the fixed media part with the instrumental in order to create a perceptual ambiguity during performance.

The method used to achieve this was to sample both the percussion instruments and the trombone playing extended playing techniques and use these recorded sounds in the fixed media part together with new sounds created by means of filtering based on the spectral content of the recorded sounds.

As in *Utresa*, *Joker* and *The Ringing Stone of Håga*, I used Sethares' dissonance curve in order to create scales based on spectra. As in *Joker*, the idea for this piece was to combine harmony based on several different spectra. In *Joker* I had investigated if there was a way to combine the different sets of harmonies and maintain a feeling of unity throughout the whole composition. In *Echo of Silence* I wanted to see how this would work with instruments involved.

Compositional process

In order to create an overall structure I used material from an older fixed media piece, *Li Shin Chuen* (1998). *Li Shin Chuen* was based on the sounds of a martial arts instructor performing a series of movements based on a Chinese Kung Fu-form named "A Formed Fist" (Li Shin

Chuen). In *Echo of Silence* I wanted to use a rhythmic analysis of this sound in order to structure the rhythmic material throughout the piece (see Figure 2.98).

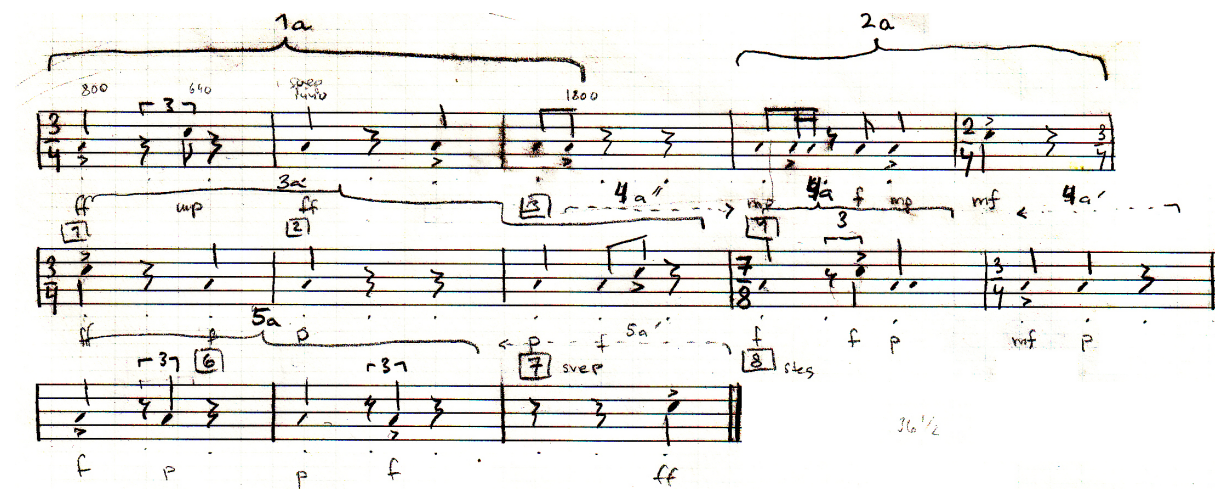


Figure 2.98. The rhythm from *Li Shin Chuen*.

The musical structure (M) was based on the rhythm. The spectra of the sound material were used to structure the harmonic content (H) in the piece. The overall time structure (T) was then based on the harmonic progression of different spectra and all sounds were edited or created with the harmonic structure in mind (see Figure 2.99).

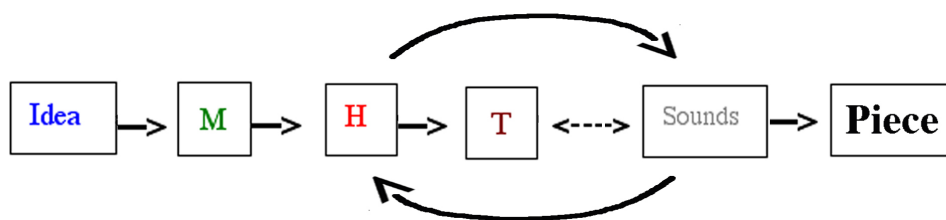


Figure 2.99. The compositional process in *Echo in Silence*.

Sound material and sound processing

Sound materials from six percussion instruments were analysed and used: two terracotta pots (one large and one medium), a large tam tam, a wind chime, a metal plate and a dubaci. The trombone sounds used consisted mostly of extended playing techniques such as breathing sounds, circular breathing, noise sounds, clicks and glissando multiphonics created by singing when playing the trombone.

The fixed media sounds were based mostly on the recorded instrumental sounds and filtered noise. Composer and programmer Sten-Olof Hellström developed a filtering tool in

Max/MSP, a tool in which I could analyse a sound spectrum and map the partials of the sound onto a 25-band filter with full control of each filter band regarding frequency, gain and Q-value (see Figure 2.100 and Figure 2.101).

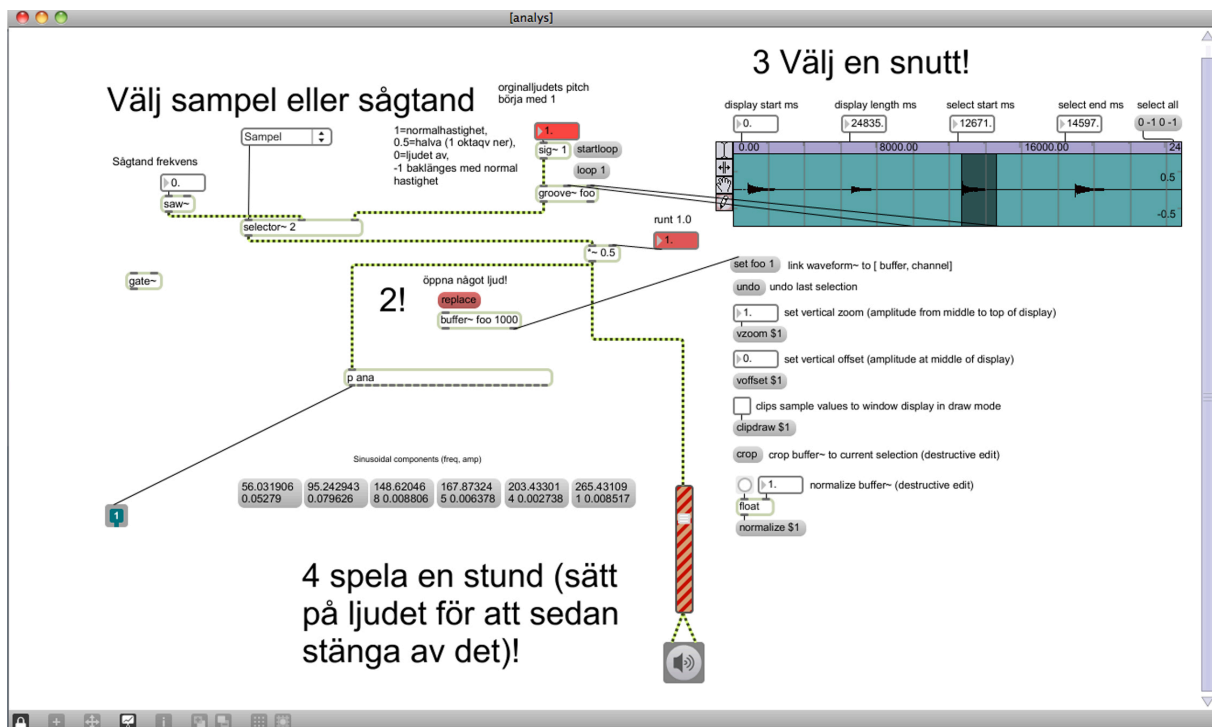


Figure 2.100. The Max/MSP analysis patch made by Hellström.

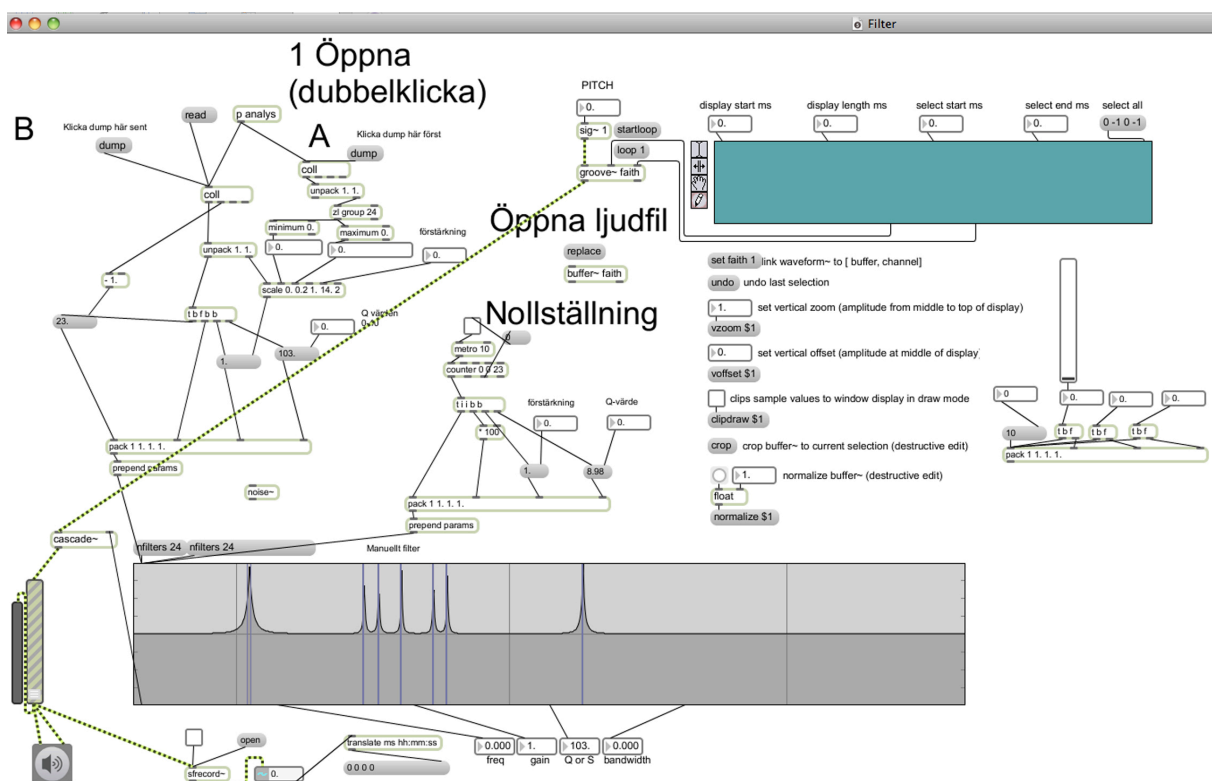
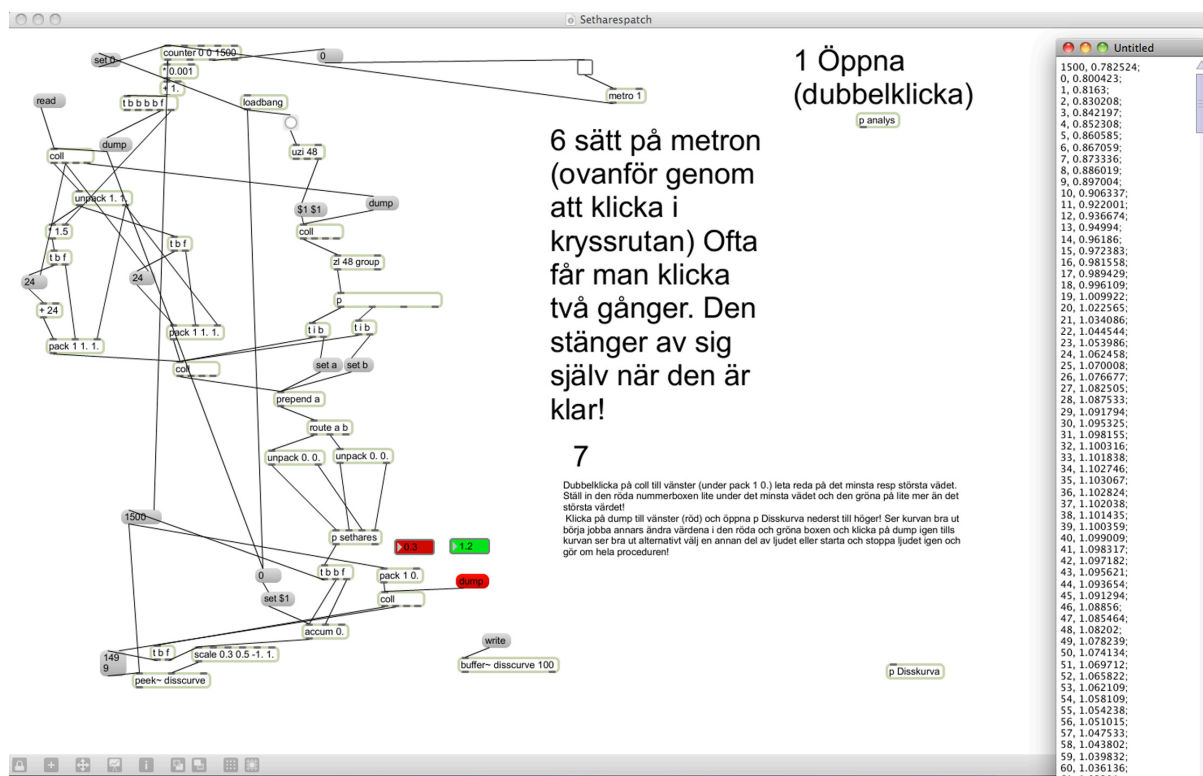


Figure 2.101. The Max/MSP filter patch made by Hellström.

In order to use Sethares' dissonance curve a new tool in Max/MSP needed to be constructed in order to make the process of analysing sounds, creating a dissonance curve and calculating scales more efficient and quicker. As mentioned in page 127, I initiated a project at the Royal College of Music in Stockholm in order to develop tools in Max/MSP-environment with Hellström, a project that will be completed in 2011. In *Echo of Silence* I used the prototypes for this project, among others a tool where a sound may be spectrally analysed and a dissonance curve created based on the specific place where the sound is played. The patch was based on three steps. The first step was to analyse the sound with a similar patch to that in the filtering tool (see Figure 2.100). The second step was to do the calculation of the dissonance curve (see Figure 2.102).



The third step was to perform the layout of the dissonance curve as seen in Figure 2.103.

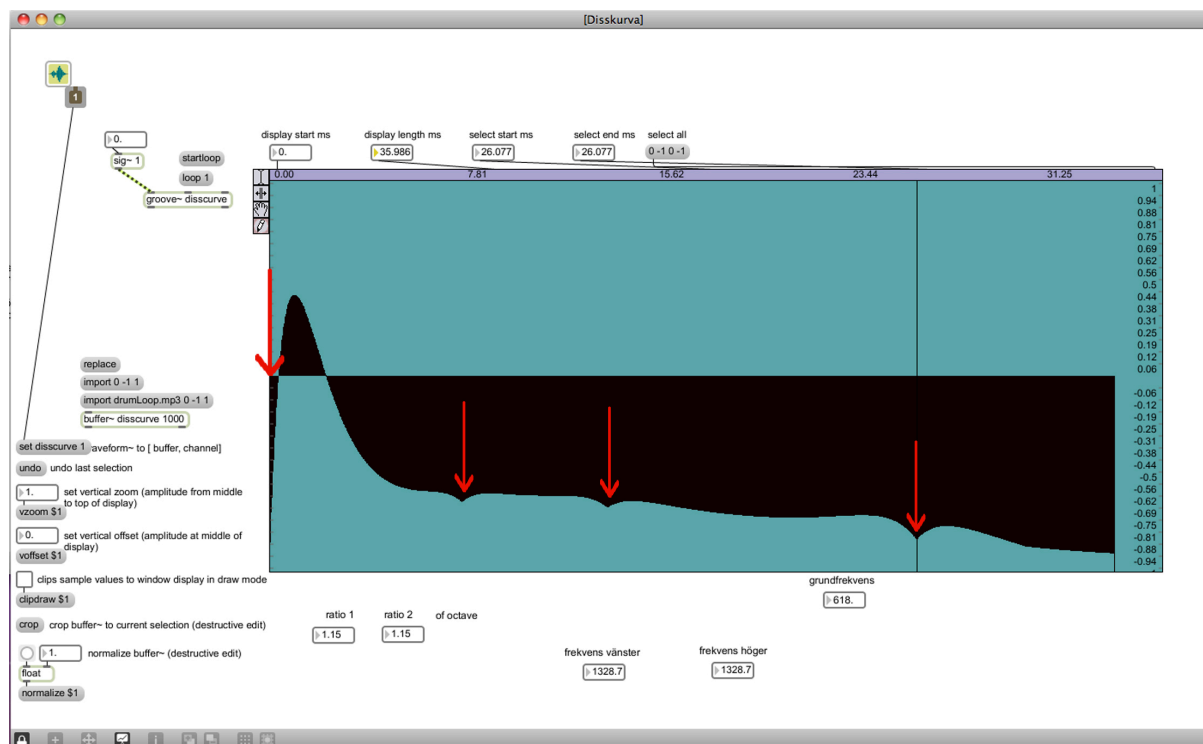


Figure 2.103. The layout of the dissonance curve, a Max/MSP patch made by Hellström.

The red arrows seen in Figure 2.103 are not included in the patch and have been placed there afterwards in order to illustrate the scale steps that can be read from the dissonance curve.

The improvement with these patches made by Hellström is that one may perform the analysis and the calculation of the dissonance curve in the same environment. In the earlier tools I had to first perform the analysis of a sound in one program such as Audiosculpt, read the frequency and amplitude values from the sonogram and then translate these into other formats in the Microsoft Excel-patch that contained Sethares' algorithm (used for calculating the dissonance curve).

Harmonic development throughout the piece

The overall form of the piece is a transition from a spectrum based on four different percussion sounds such as the terracotta pots, the tam tam and the dubaci to a spectrum based on the wind chimes. All five instruments were analysed and an approximate table of frequencies for each one of them were made (see Figure 2.104).

Echo in Silence begins with a theme based on the terracotta sounds together with the dubaci. This theme opens up three different sections of the piece (at 0'00, 3'04 and 4'51) based on different parts of the Kung-Fu-rhythm. The whole rhythm can be heard in the fixed media part at 6'54 played with samples of the wind chime.

The first part of the piece in the fixed media part focuses on the tam tam spectrum and its transpositions as an underlying structure. The first part then modulates to the merged spectrum of the pots and the dubaci, which is the foundation for the second part that begins at bar 51 (3'04). The wind chime spectrum is introduced at 4'20 and is used as the underlying harmonic structure merged together with the two pots and dubaci spectra (see Figure 2.105). The piece ends with the spectra of the wind chimes in the fixed part accompanied by the instruments playing on various crotales, pots and the bell of the trombone. The percussionist at the end plays on the original wind chime.

Pots	Frekvens	Cent	Index	Frekvens	Cent	Index	Frekvens	Cent	Index	Frekvens	Cent	Index	Frekvens	Cent	Index	Frekvens	Cent	Index	index/skala
Wind chimes																			
Dubaci	181,4	401,6364928	1,132864056	1,265	229,471	1,69	306,566	1,855	336,497	2,388	433,1832	454,600	215,9527014	215,9527014	1,132864056	406,9328347	406,9328347		1,265
	228,77	1306,311613	1,192256929		259,95945		347,2976		381,20536		490,73768	515,000	88,45754118	304,4102426	1,192256929	229,471	908,3564046		1,69
	385,8				273,58839		365,50544		401,19088		516,46567	542	395,2032319	699,6134746	1,498020238	306,566			1,855
	455	1591,905218	1,498020238		343,7522		459,24207		504,07932		648,9172	681	105,9935368	805,6070113	1,592608887	336,497	1069,618841		1,855
	495,8	1740,563589	1,592608887		365,45755		488,23974		535,90811		689,89141	724	414,7403549	1220,347366	2,023757149	437,2259683	1506,844809		2,388
	544	1901,169005	2,023757149		464,39358		620,41513		680,98821		876,6576	920	213,900328	1434,247694	2,289925209	433,1832			
	681	2289,996179	2,289925209		525,47143		702,01321		770,55296		991,95713	1041	512,9077424	1947,155437	3,079630444				
	725	2398,379085	3,079630444		706,68588		944,10999		1036,2864		1334,0442	1400	531,3766599	2478,532097	4,186097668				
	920	2810,730071	4,186097668		960,58802		1283,3152		1408,6093		1813,3472	1903	106,7120754	2585,244172	4,452265728				
	1040	3022,966682	4,452265728		1021,6659		1364,9133		1498,1741		1928,6467	2024	411,416427	2996,660599	5,646722393				
	1400	3537,538141	5,646722393		1295,759		1731,0931		1900,1051		2446,0653	2567							

Figure 2.105. The scale steps for the sounds of the two pots, dubaci and wind chimes based on the results from Sethare's dissonance curve.

Performance

The score is notated with a tempo of crotchet = 60 and the performers used a click-track during performance, as timing with the fixed media part is important. The percussion instruments had microphones placed close to each instrument and the trombone had a separate microphone, as the trombone part contained quiet sounds that needed to be enhanced.

Evaluation

Again I found the method of sampling the instruments and integrating the spectral content of the fixed media part with the instrumental, a fruitful way of creating a perceptual ambiguity during performance.

The new Max/MSP-patches saved a lot of time and effort compared to the older tools and they inspired me to work with Sethare's dissonance curves in other ways than before. In *Echo of Silence* I merged several sounds together, thus creating a new sound, and calculated a dissonance curve based on that new, merged sound. For example the two terracotta sounds, the dubaci and the wind chimes were merged together and scales based on these merged sounds were used in the middle of the piece, in order to make the transition from the first spectrum to the spectrum of the wind chimes.

I found the method of combining different spectra based on instrumental sources in order to create an underlying harmonic structure very inspiring and successful, a method that I will research further many years to come.

Chapter 3: Conclusion

The works commented on in Chapter 2 illustrate the main aspects of my compositional techniques based on research in the field of psychoacoustics outlined in Chapter 1.8-1.11 and different strategies of structuring sound material presented in Chapter 1.2.

Computers offer the composer a starting point which is clearly more revolutionary than present day instrumental music. The computer makes it possible – and one cannot escape from this – to look anew at the received ideas of instrumental music. I believe, however, that the richest creative possibilities are at present to be found in the combination of computer resources and acoustic instruments: one thus comes fully to exploit their respective advantages and to compensate for their deficiencies.⁹⁷

The quotation from Kaija Saariaho in 1987 sums up my compositional approach in 2010 and all instrumental and mixed works in this portfolio illustrate my work based on the analysis of sounds. In *Taal Bundu* the analysis made by computer was not the harmony of the imported melody used, but the analysis of tabla sounds I transcribed into traditional equal 12-tone pitches. In the other instrumental works such as *Ti Chor*, *Ytspänning* and *Echo in Silence*, the analysis of sound in software programs worked as a foundation for the pieces.

In order to explore harmony I have used computer programs to analyse sound spectra and have created scales based on algorithms such as the Sethares' dissonance curve. Even though the results from dissonance curves based on inharmonic spectra might not always apply to traditional instruments, they turned out to work very well with mixed works such as the last piece in the portfolio, *Echo in Silence*.

In my electroacoustic work such as *Utresa*, *Joker* and *The Ringing Stone of Håga* I feel that I have found a satisfactory method to create harmony within my pieces using the dissonance curve as a tool to construct scale steps that might work as sensory consonant intervals. I have explored different methods of structuring harmony in time in works such as *Ti Chor*, *Med lekande Kval*, *Within a Dream*, *Utresa*, *Joker*, *Taal Bundu*, *Ytspänning* and *Echo in Silence* and I will continue this research hoping that it will inspire my future creative work for many years to come.

⁹⁷ Saariaho, K., 'Timbre and harmony: interpolations of timbral structures', *Contemporary Music Review*, Vol. 2, Issue 1, (1987), p. 130.

Working with external musical factors as in *Med lekande kval*, *Within a Dream* and *Taal Bundu* and with visual images as in *Utresa* and *Joker*, proved to be interesting methods of structuring material as they created a frame work within which I could explore compositional strategies that were new to me. The collaborative aspect working with a textile artist, other composers and musicians in works such as *Ti Chor*, *Reflections*, *Within a Dream*, *Utresa*, *Joker*, *Taal Bundu* and *Echo in Silence* was very inspiring and is a path that I will continue to research. New projects with The Stockholm Saxophone Quartet, The Axelsson and Nilsson duo (percussion and trombone), composer Jens Hedman, textile artist Britt-Marie Hansson and composer/soprano Carin Bartosch-Edström are already planned.

In Chapter 2 I have also described the process of developing new tools in order to work with harmony. In the first piece of this portfolio, *Ti Chor*, I used existing software at the time such as Alchemy and Turbosynth. In *Mayfly* and *Clandestine Parts* I explored filtering techniques in software programs such as Sound Designer, ProTools, Audiosculpt and Metasynth. As I continued my research in harmony I needed to construct my own tools in Max/MSP in order to modulate with glissando techniques, a method used mostly in *Utresa* and *Joker*. Also tools to work more efficient with Sethares' dissonance curve and filtering techniques were developed with the assistance of Sten-Olof Hellström for the last piece, *Echo in Silence*. I have ideas for other tools that I would like to develop in the future together with Hellström. For example I would like to create a tool that enables one to create a spectrum derived from a scale, a reverse process of the Sethares dissonance curve.

Through the works included in the portfolio I feel that I have developed my own voice as a composer with new methods of working with pitch and with harmony as an underlying structure. With the works *Utresa*, *Joker* and *The Ringing Stone of Håga* I have clearly demonstrated how I have re-invented harmony in my electroacoustic music. In *Echo in Silence* I have used instruments and fixed media in combination with research in psychoacoustic consonance and dissonance in order to close the circle in regards to the research that began with *Ti Chor*.

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Appendix 1a: Paulina Sundin – selected works list not included in portfolio

Klotet (2003)

- fixed media in 5-channel: 5'25

Klotet (Image 1) was one of five pieces included in the project *Earblink* commissioned by the Textile Museum in Borås and Musik i Väst. Other pieces created for *Earblink* were *Utresa* and *Joker*. Re-mixed versions of the already existing pieces *Med lekande kval* and *Clandestine Parts* were also part of the project (see Image 2).

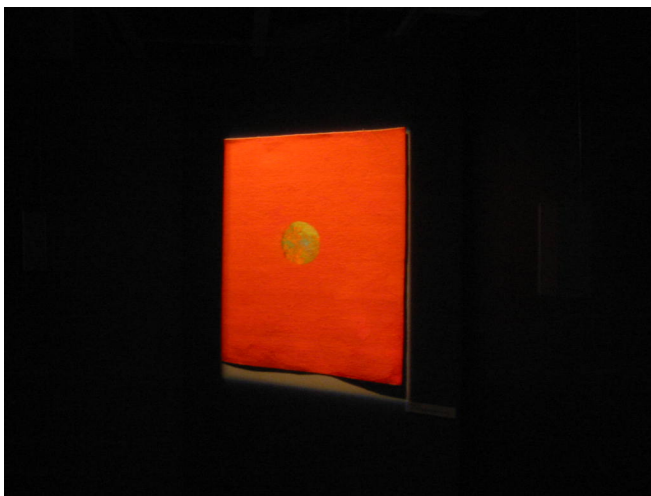


Image 1: The textile *Klotet* made by the textile artist Britt-Marie Hansson

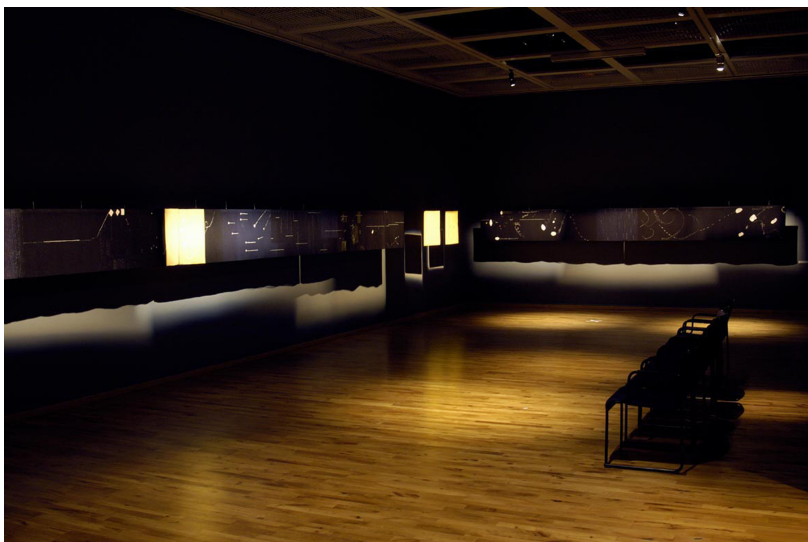


Image 2: The textiles *Clandestine Parts* (right) and *Med lekande kval* (left) made by Britt-Marie Hansson.

Appendix 1b: Paulina Sundin – selected works list not included in portfolio

The project *Modern Romanticism*:

***Improvisationer över Absence* (2006)**

- soprano, accordion, recorder, viola and live-electronics *: 3'00

***Improvisationer över Kristalliseringen* (2006)**

- soprano, accordion, recorder, viola and live-electronics *: 3'00

* Collaboration with the ISM-ensemble (Carin Bartosch Edström, soprano, Catharina Backman, accordion, Claudia Müller, recorder and Mikael Marin, viola). A Project funded by the Arts Grants Committee 2004.

Appendix 2: *Ti Chor* – Scales/melodies extracted from multiphonics spectra

127-134
3

c c# d d# e f f# g g# a a# b

(ingen 1: a pa
f eller B^b)

Alt

1

2

3

Bar

4

5

6

Tenor

7

8

9

Sopran

10

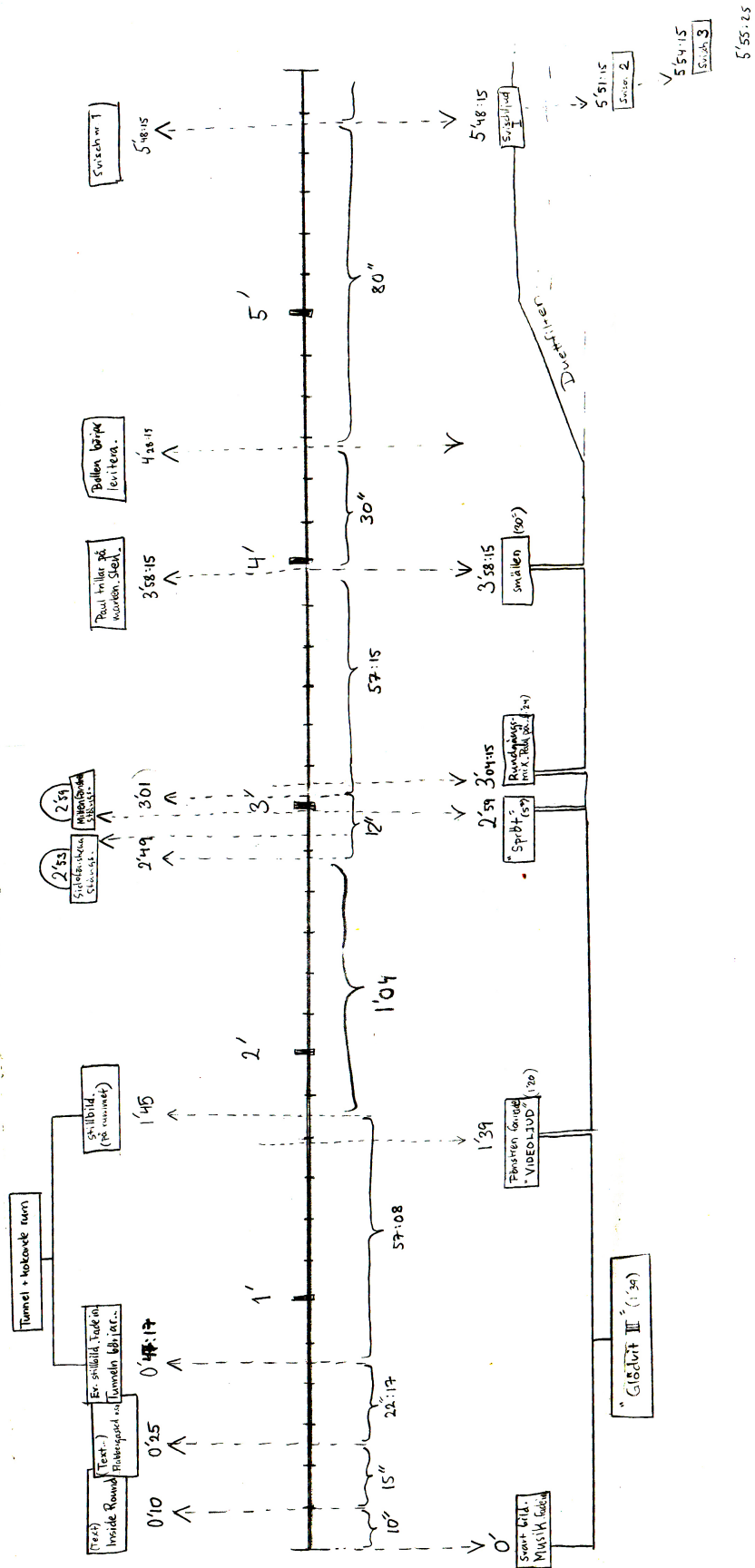
11

12

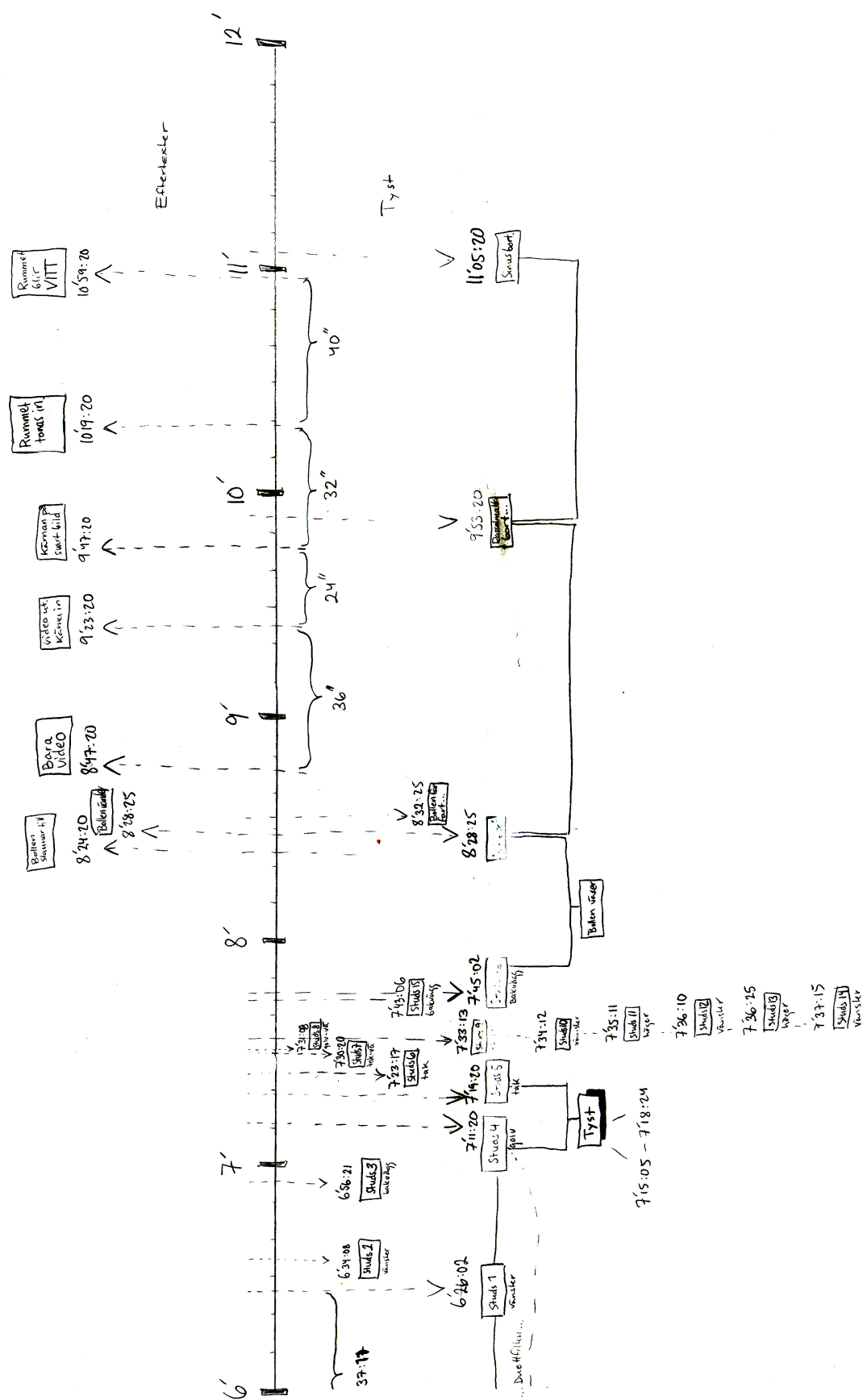
13

13

Appendix 3a: *Reflections* – Overall time-grid for Inside Round



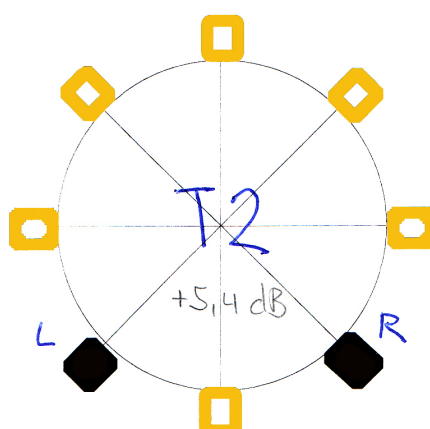
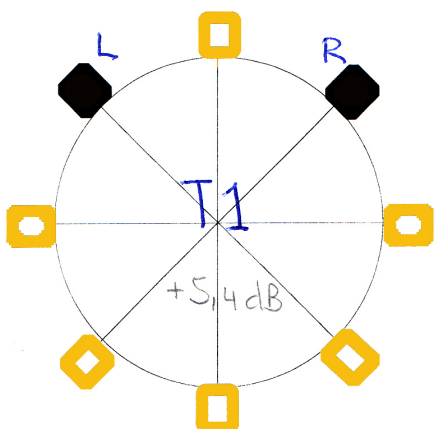
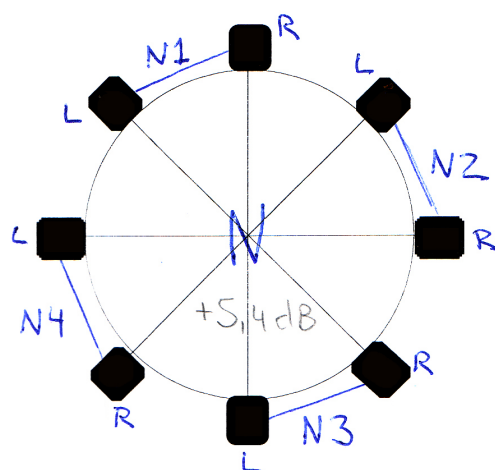
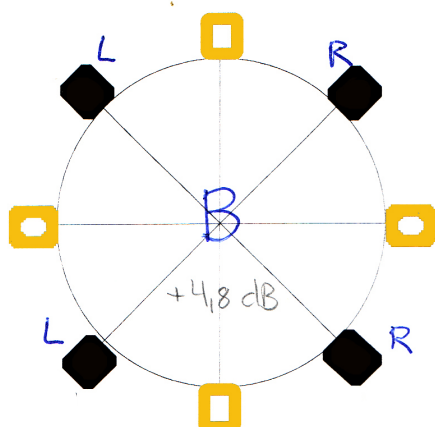
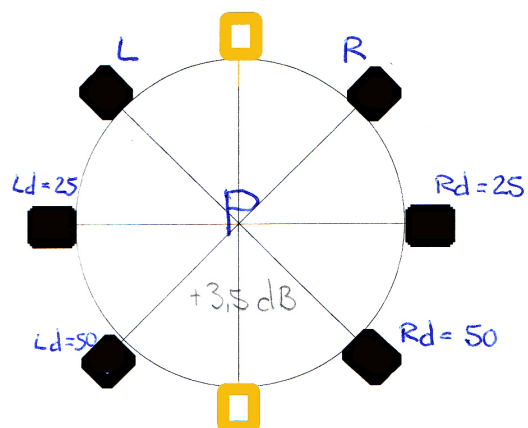
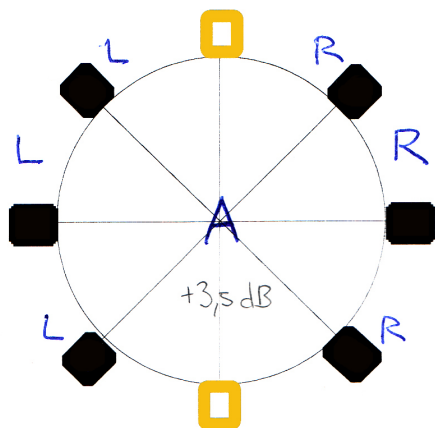
Appendix 3b: *Reflections* – Overall time-grid for Inside Round



Appendix 4a: *Reflections* – 8-channel loudspeaker configurations

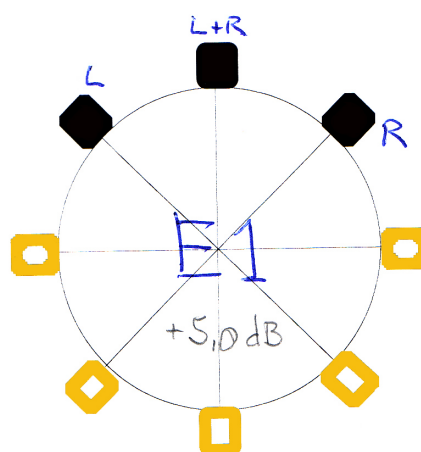
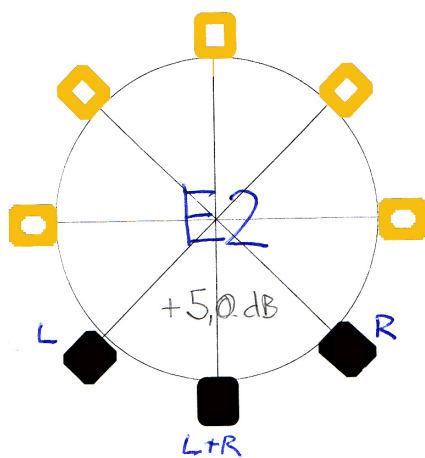
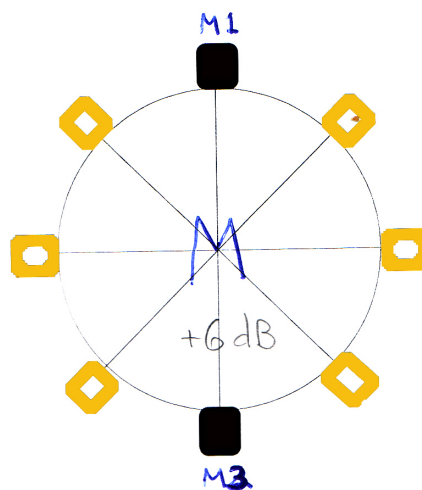
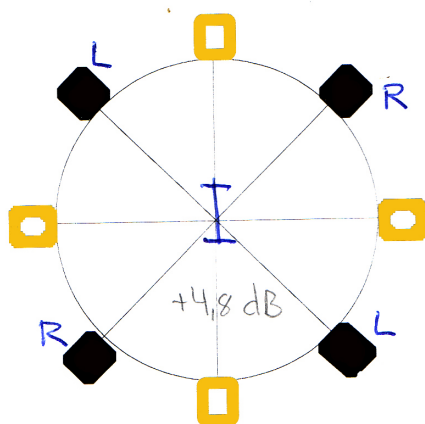
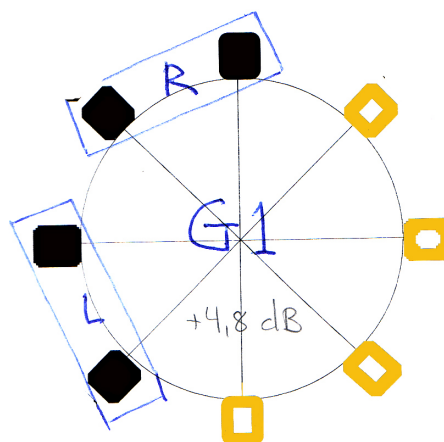
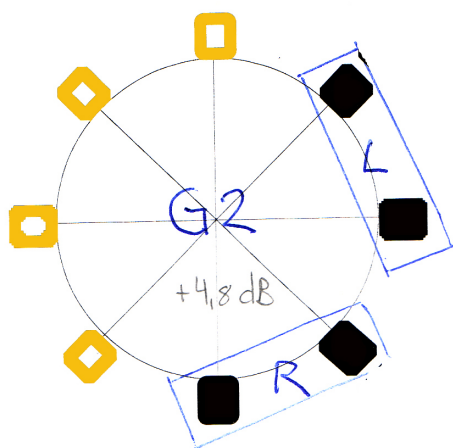
Reflections

8-kanaler



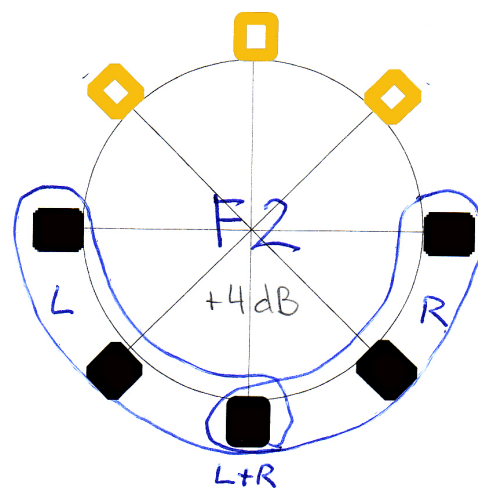
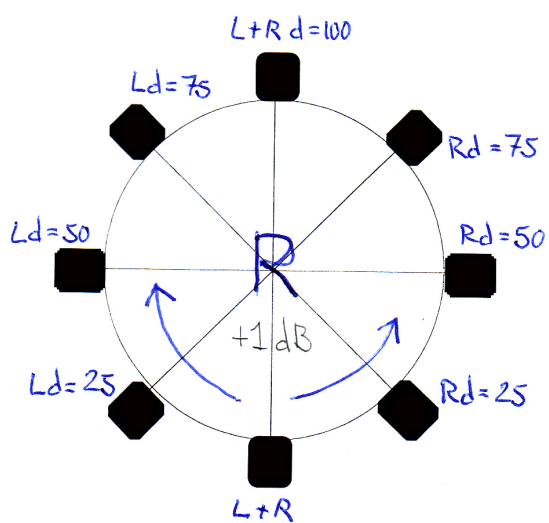
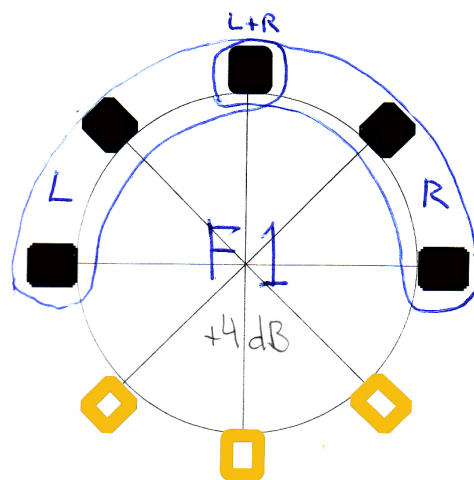
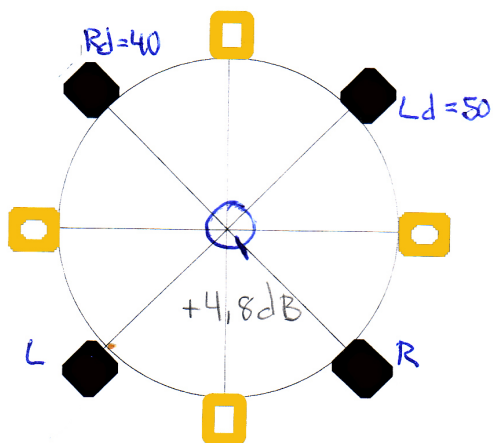
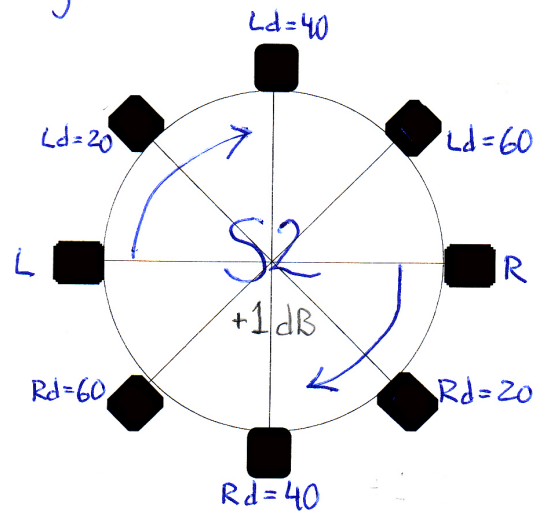
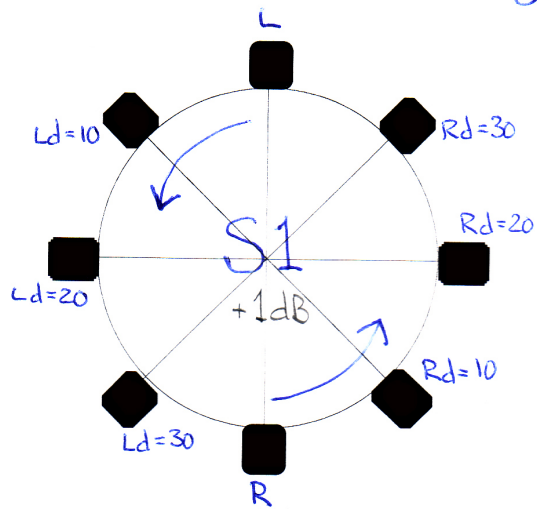
Appendix 4b: *Reflections* – 8-channel loudspeaker configurations

Reflections
8-kanaler



Appendix 4c: Reflections – 8-channel loudspeaker configurations

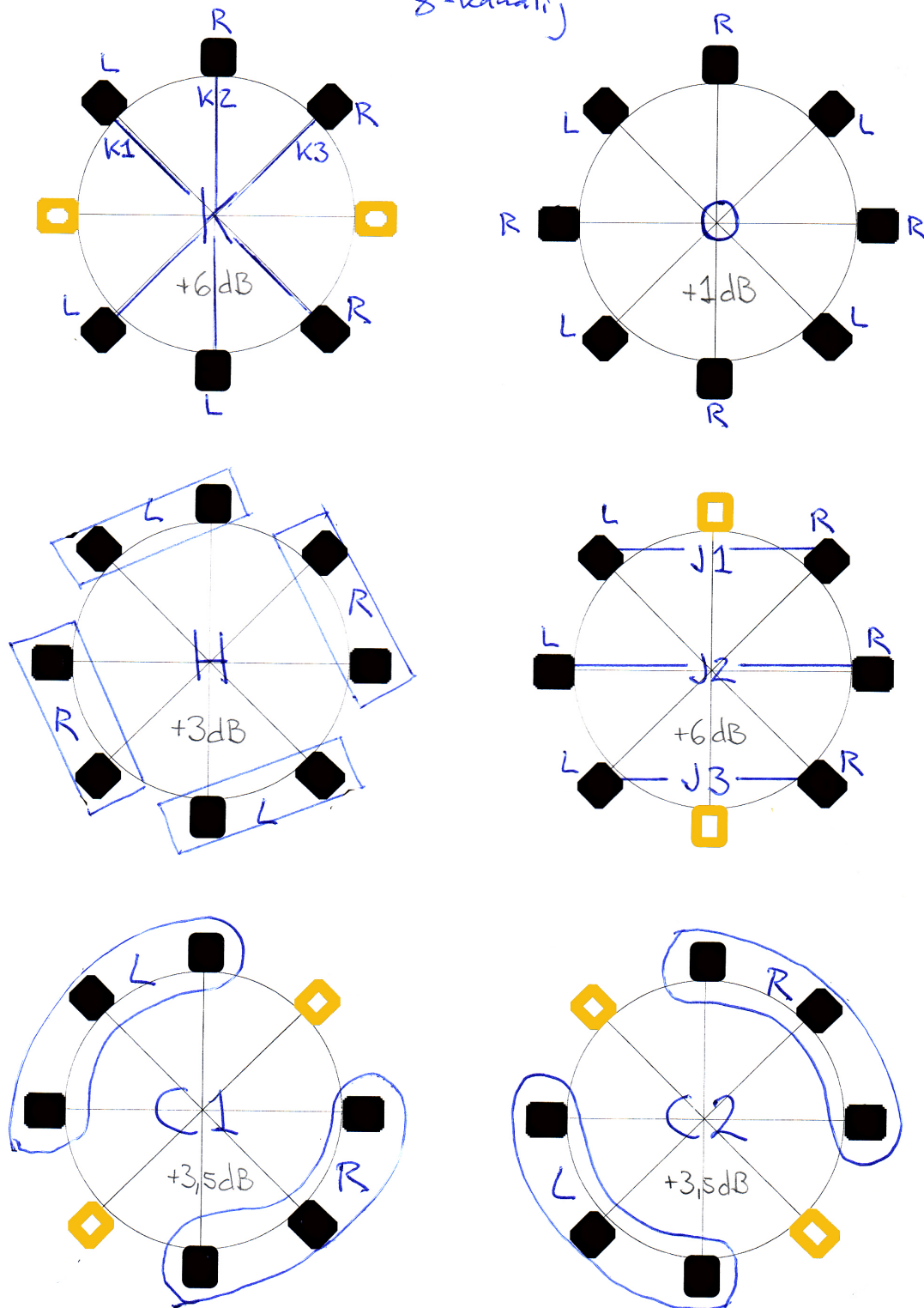
Reflections 8-kanaliġt



Appendix 4d: *Reflections* – 8-channel loudspeaker configurations

Reflections

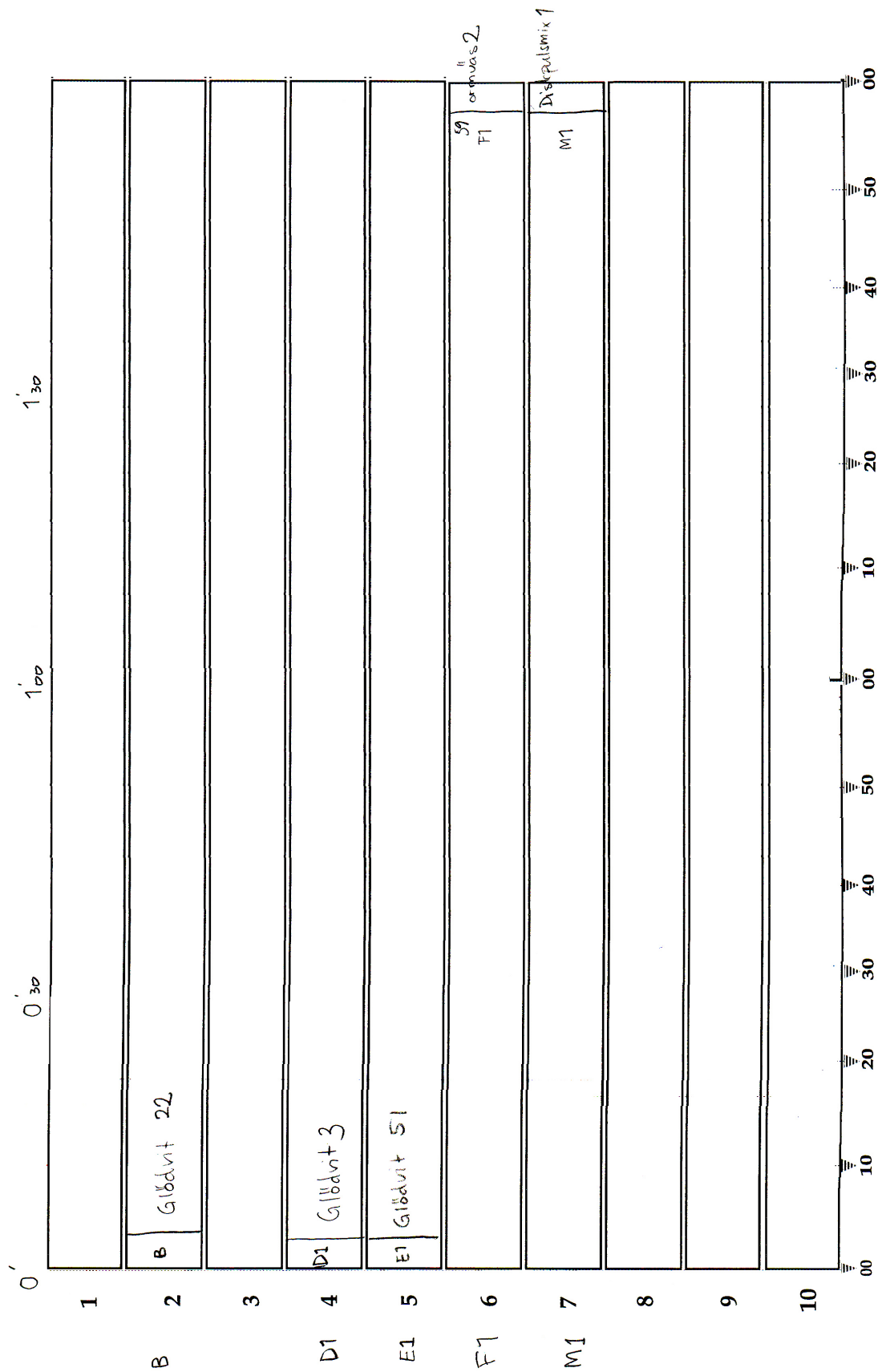
8-kanaliy



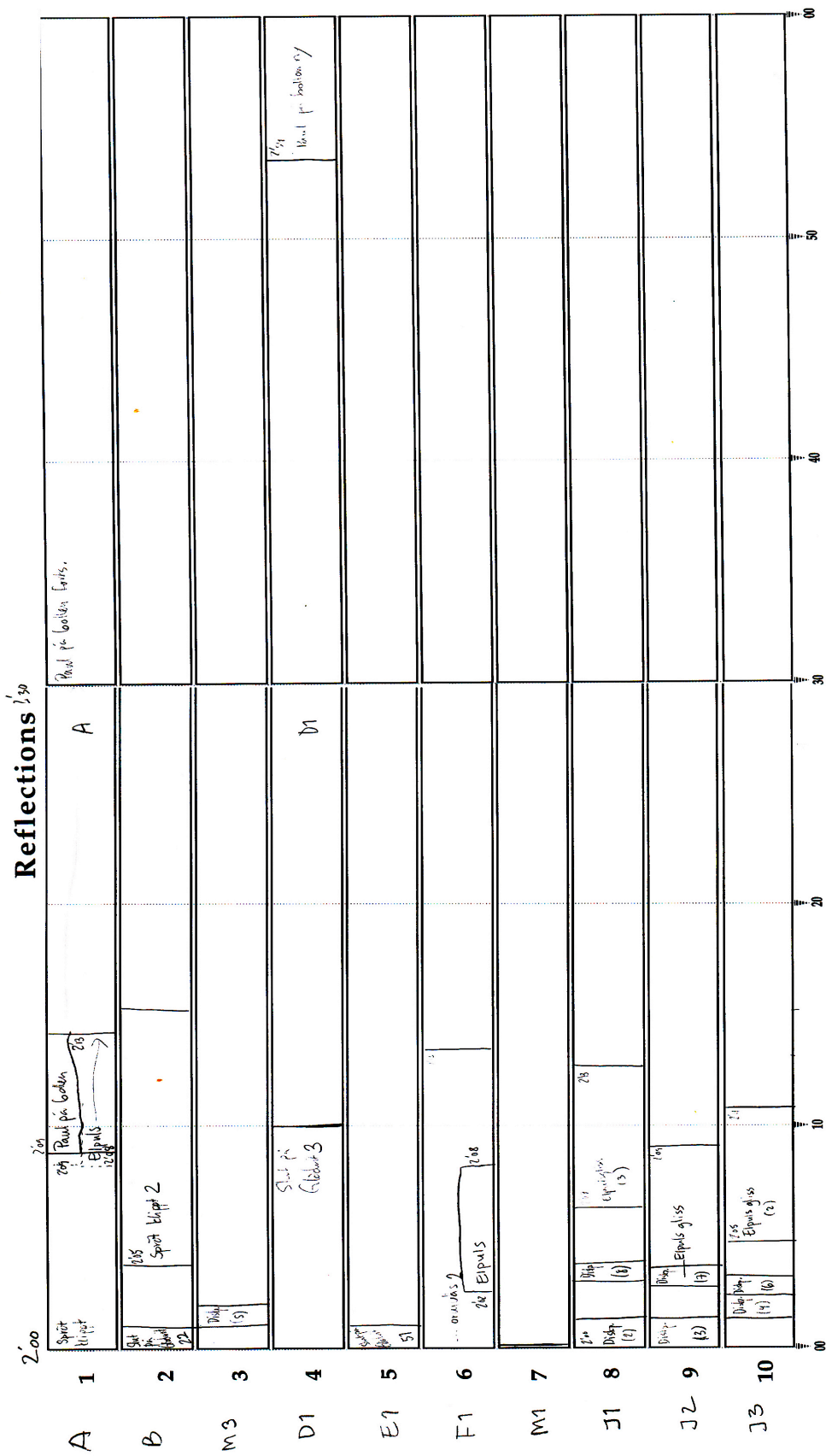
Appendix 5a: *Reflections* – Loudspeaker configuration for each sound

13/9-99

Reflections



Appendix 5b: *Reflections* – Loudspeaker configuration for each sound



Appendix 5c: Reflections – Loudspeaker configuration for each sound

Reflections		00	10	20	30
A	1	Paul på bollen 3'02			
B	2		Bruskyten 2.05.11.1 Bruskyten 3'10	3'22	3'24 Gledrev
E2	3	3'06 Tjodrev 4 rev.	3'13		
D1	4	Paul på bollen ny	3'19	3'24 Sam glass	
	5				
F1	6	3'04 Tj. drev 3'17			3'24 Sväng 8 3'28
H	7	Paul på bollen DAT take II 3'09			
	8		Bruskyten 2	3'25	
J2	9	Elpuls 1	3'16	Bruskyten 3'13	3'22
	10				

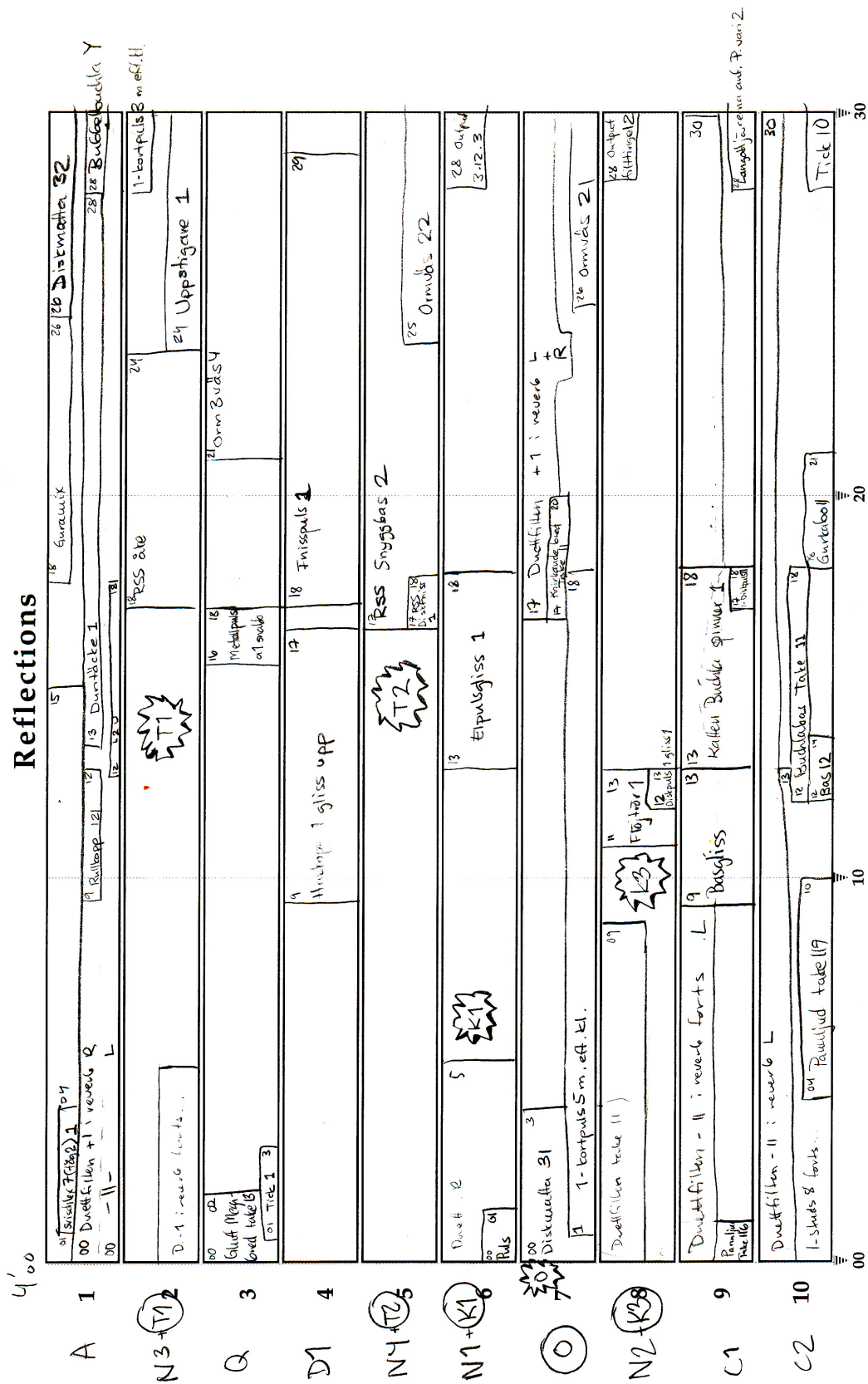
Appendix 5d: Reflections – Loudspeaker configuration for each sound

OBS! Litspänning
Reflections

A	1	Orm 3väs 1	37 Duett 6	144 Metallade	43
		335 BP 61	338	4212 Cluff mesigbed tate 1	43
B + N3	2	4000v 333	37	37	48 Duettfilen -1 i reverse L
		37	37	37	48
E2 + Q	3	E2	36	42	50
		36	36	36	50
D1	4	3730	3730	3730	3730
		3730	3730	3730	3730
N4	5	333	333	333	333
		333	333	333	333
N1	6	336	336	336	336
		336	336	336	336
H + O	7	333	333	333	333
		333	333	333	333
N2	8	333	333	333	333
		333	333	333	333
J2 + C1	9	333	333	333	333
		333	333	333	333
J3 + C2	10	333	333	333	333
		333	333	333	333

30 40 50 60

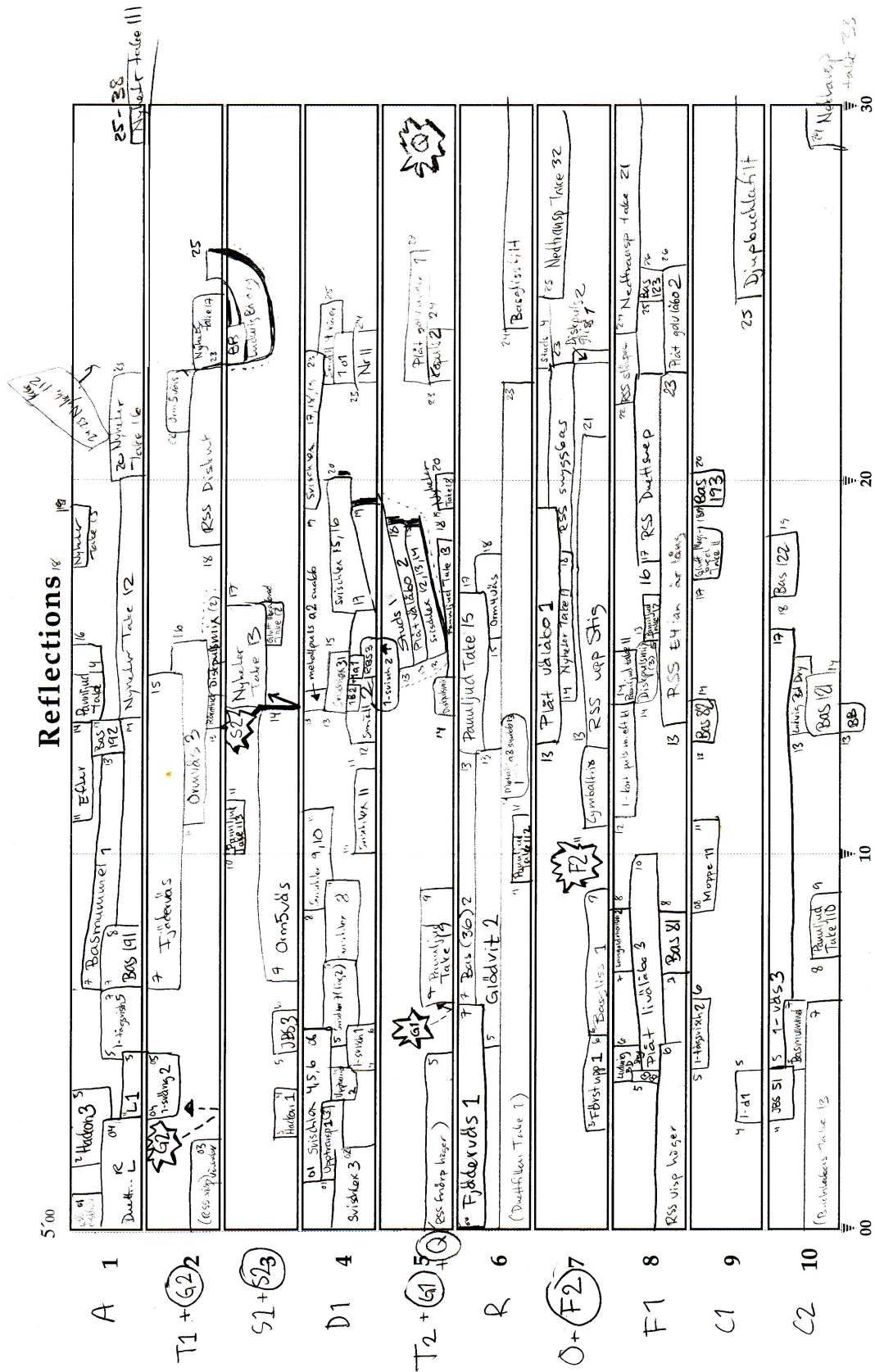
Appendix 5e: Reflections – Loudspeaker configuration for each sound



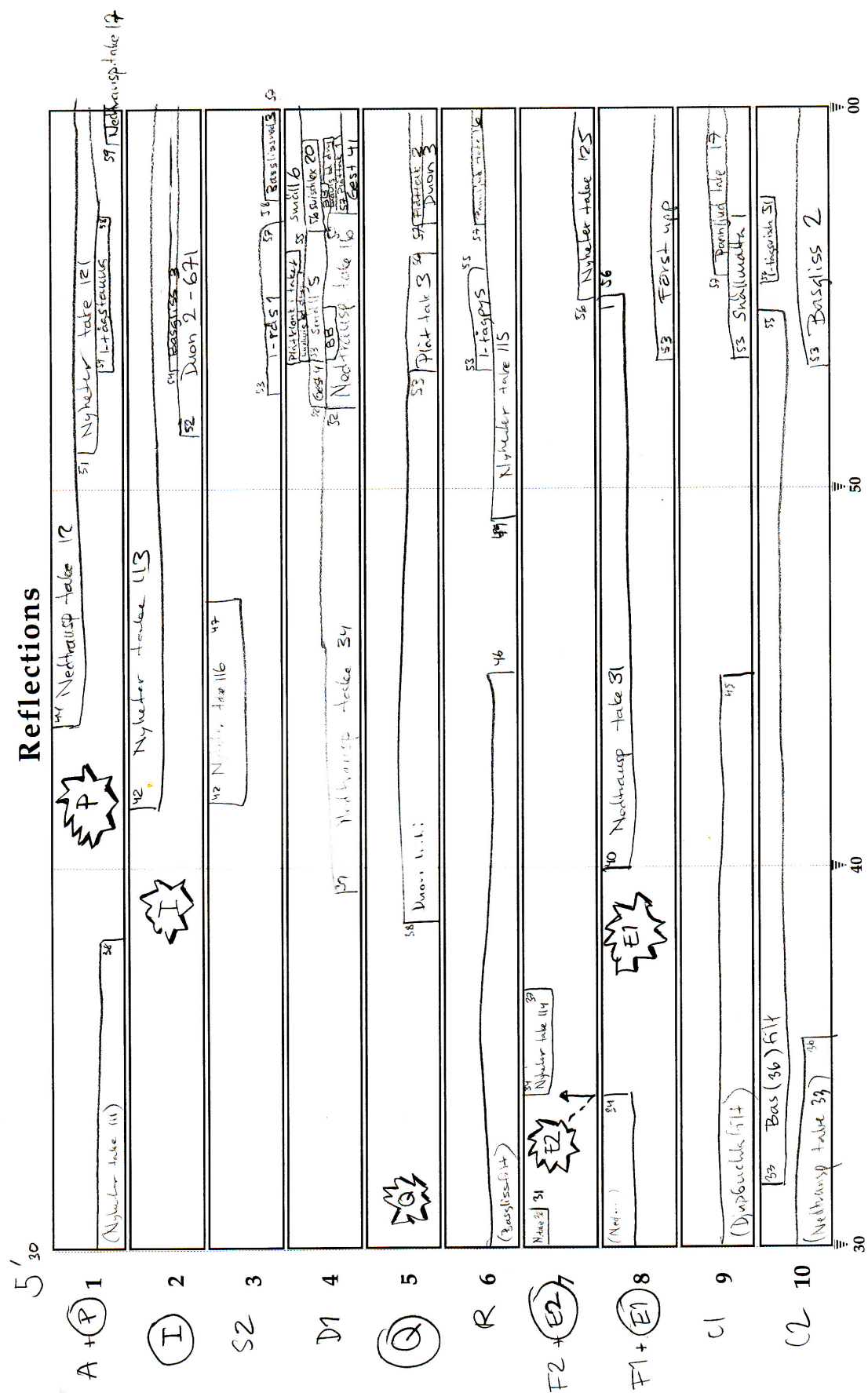
Reflections



Appendix 5g: Reflections – Loudspeaker configuration for each sound



Appendix 5h: Reflections – Loudspeaker configuration for each sound

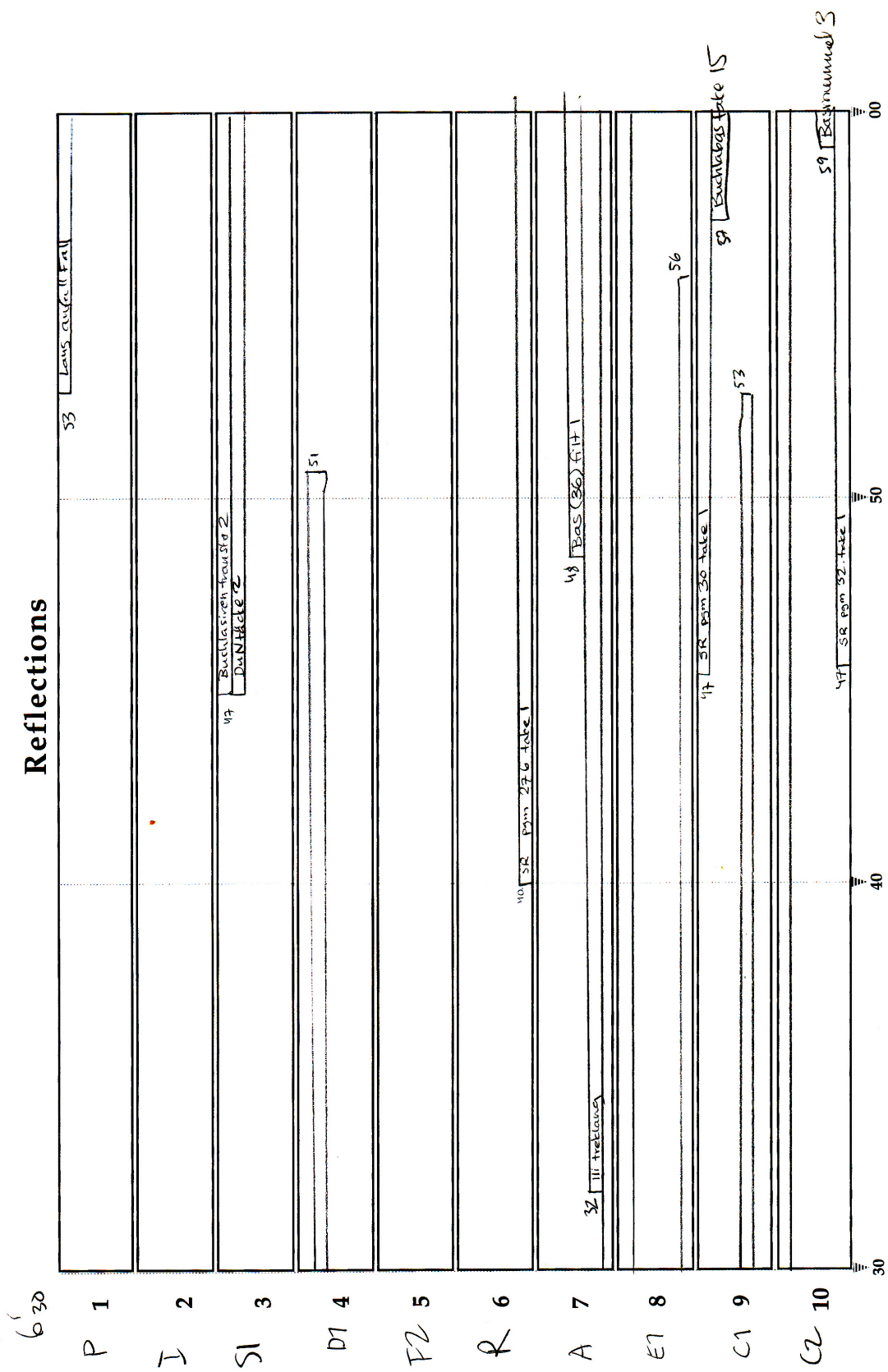


195
L
S
Stamm
also from
Väst bore forest

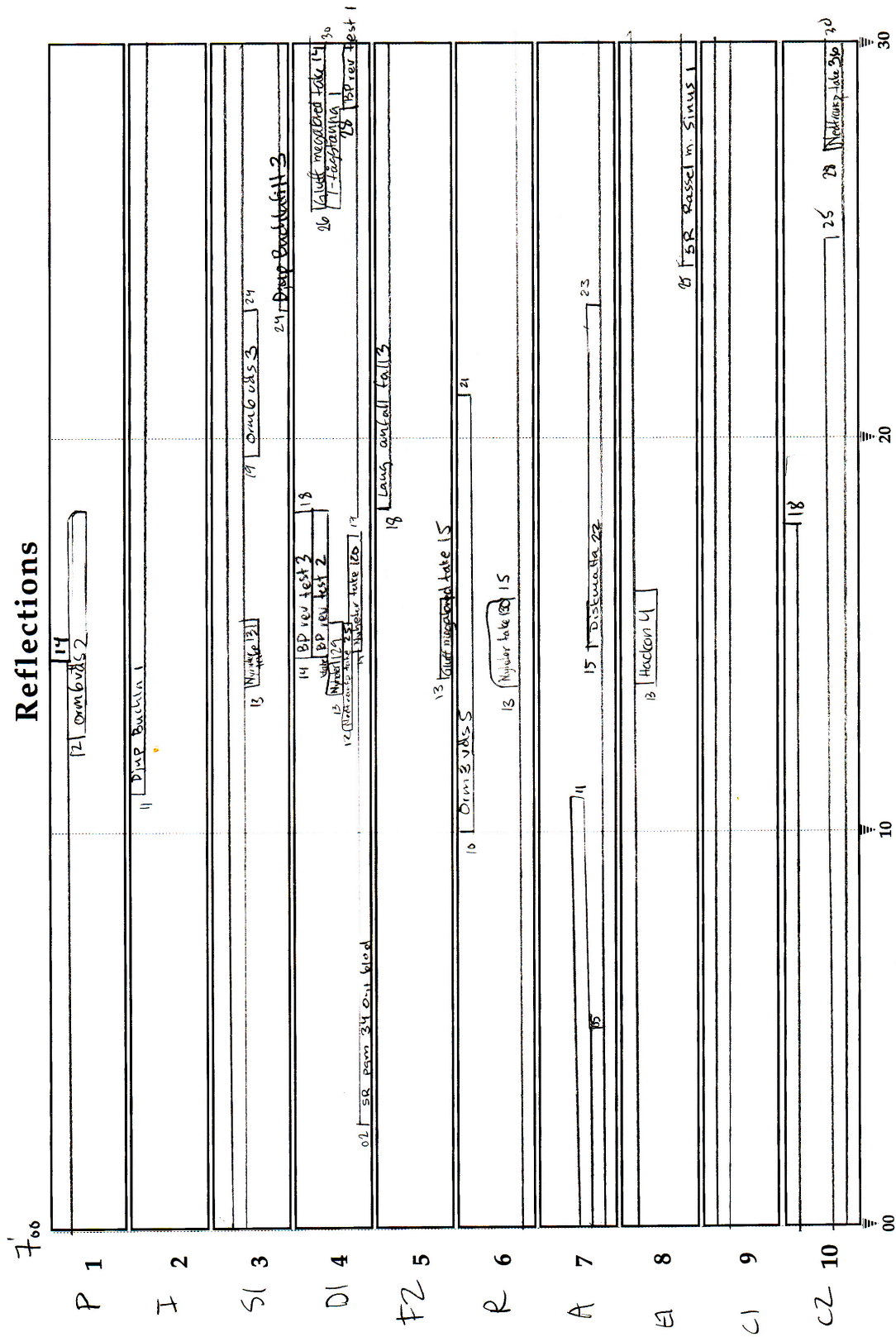
155

100

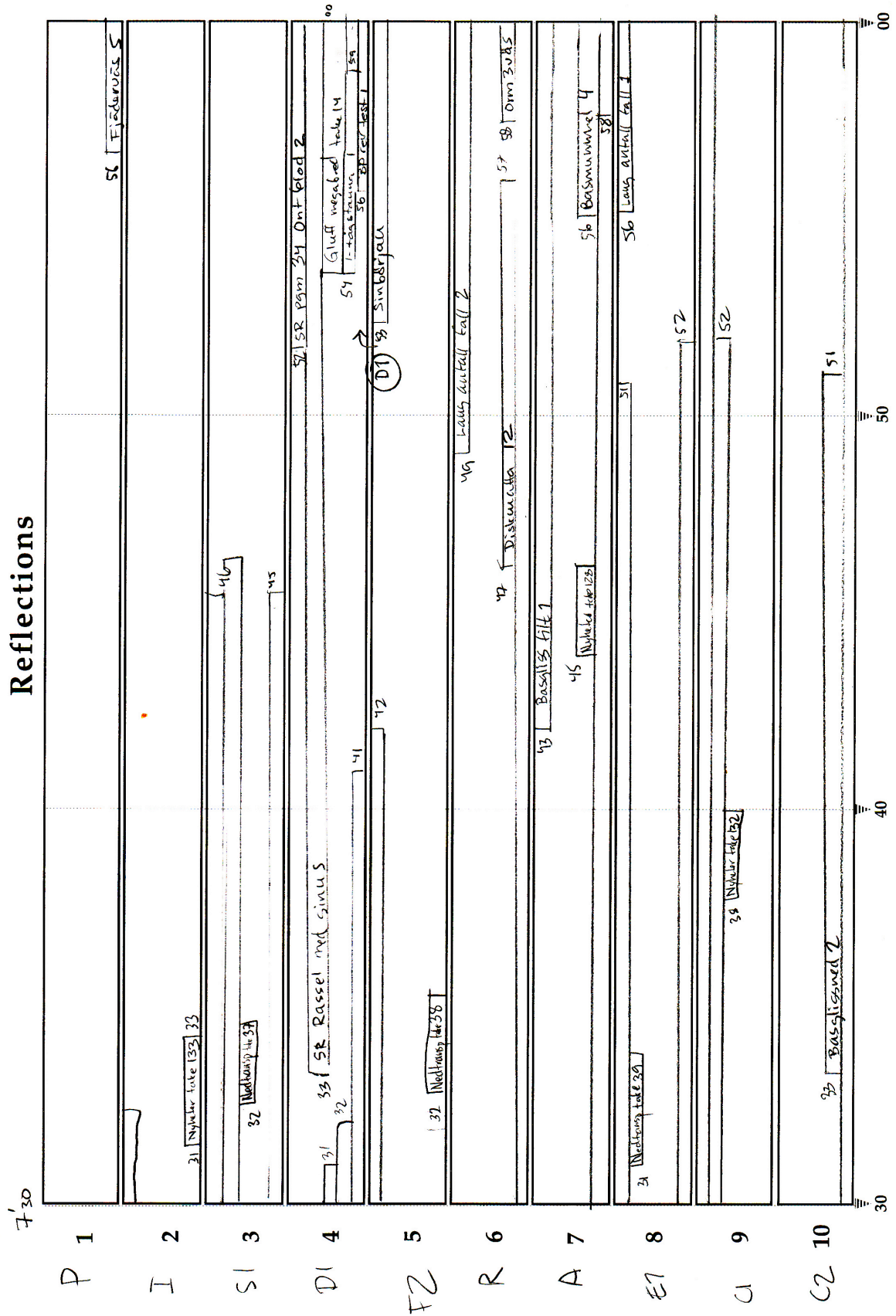
Appendix 5j: *Reflections* – Loudspeaker configuration for each sound



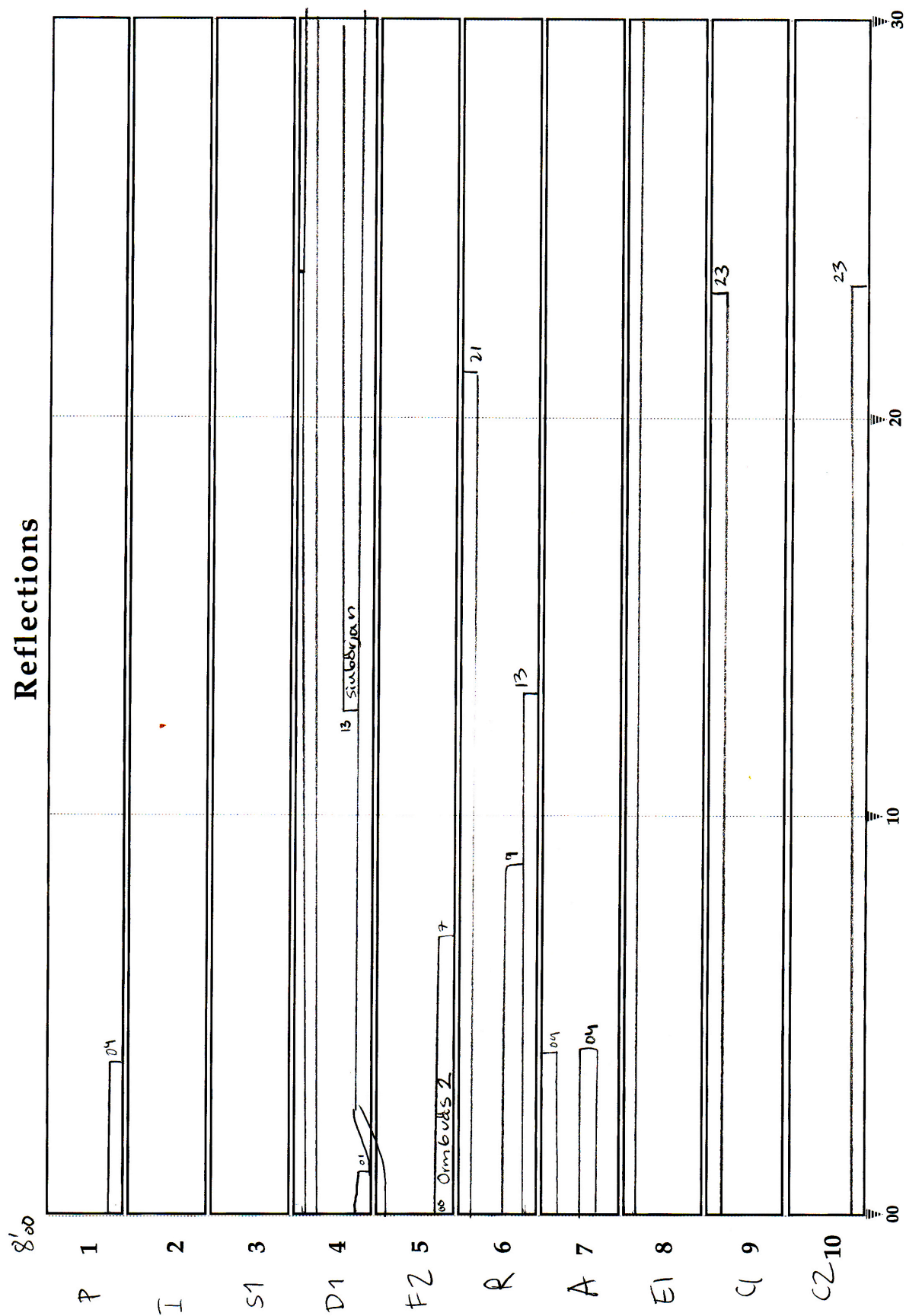
Appendix 5k: *Reflections* – Loudspeaker configuration for each sound



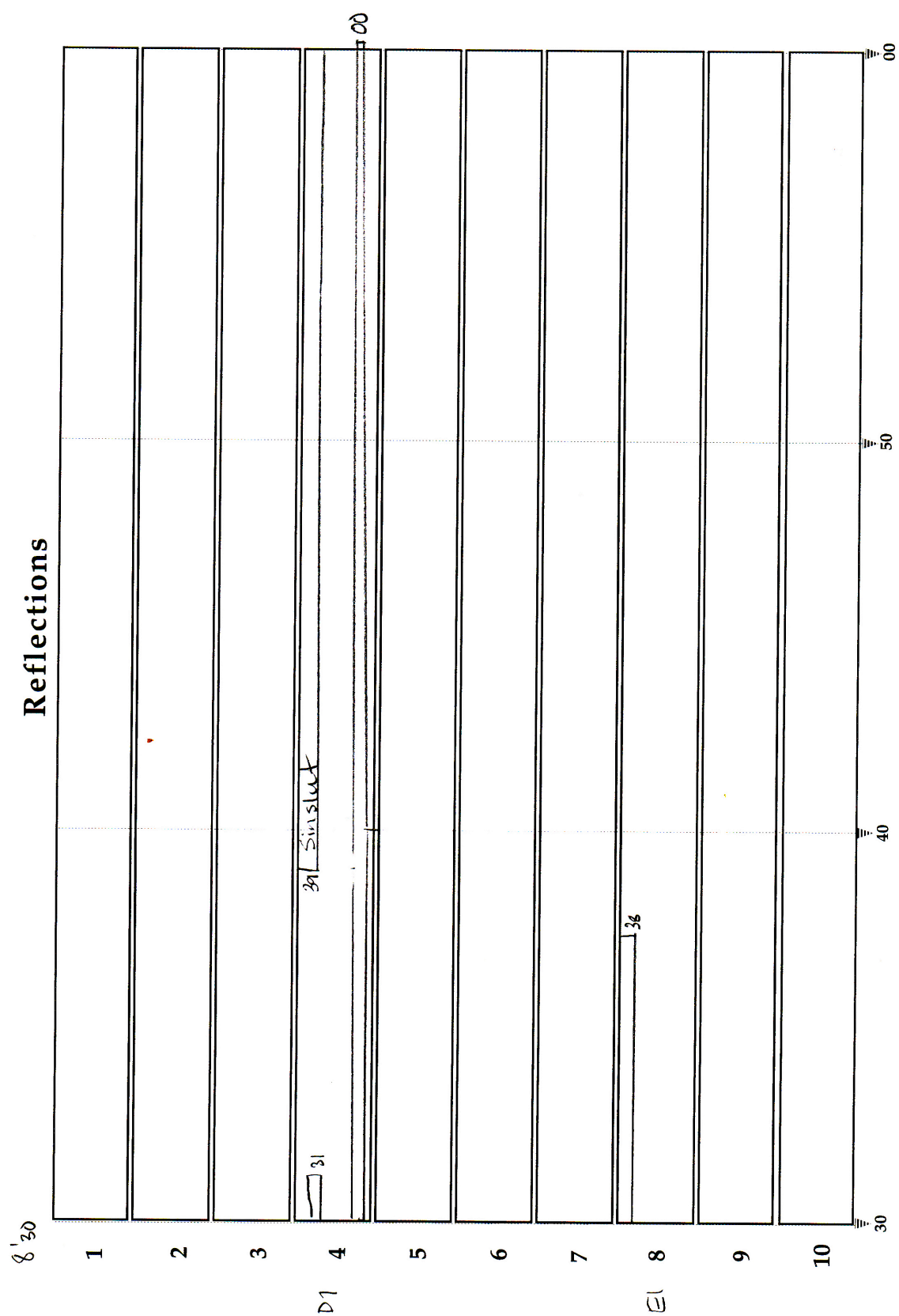
Appendix 5l: Reflections – Loudspeaker configuration for each sound



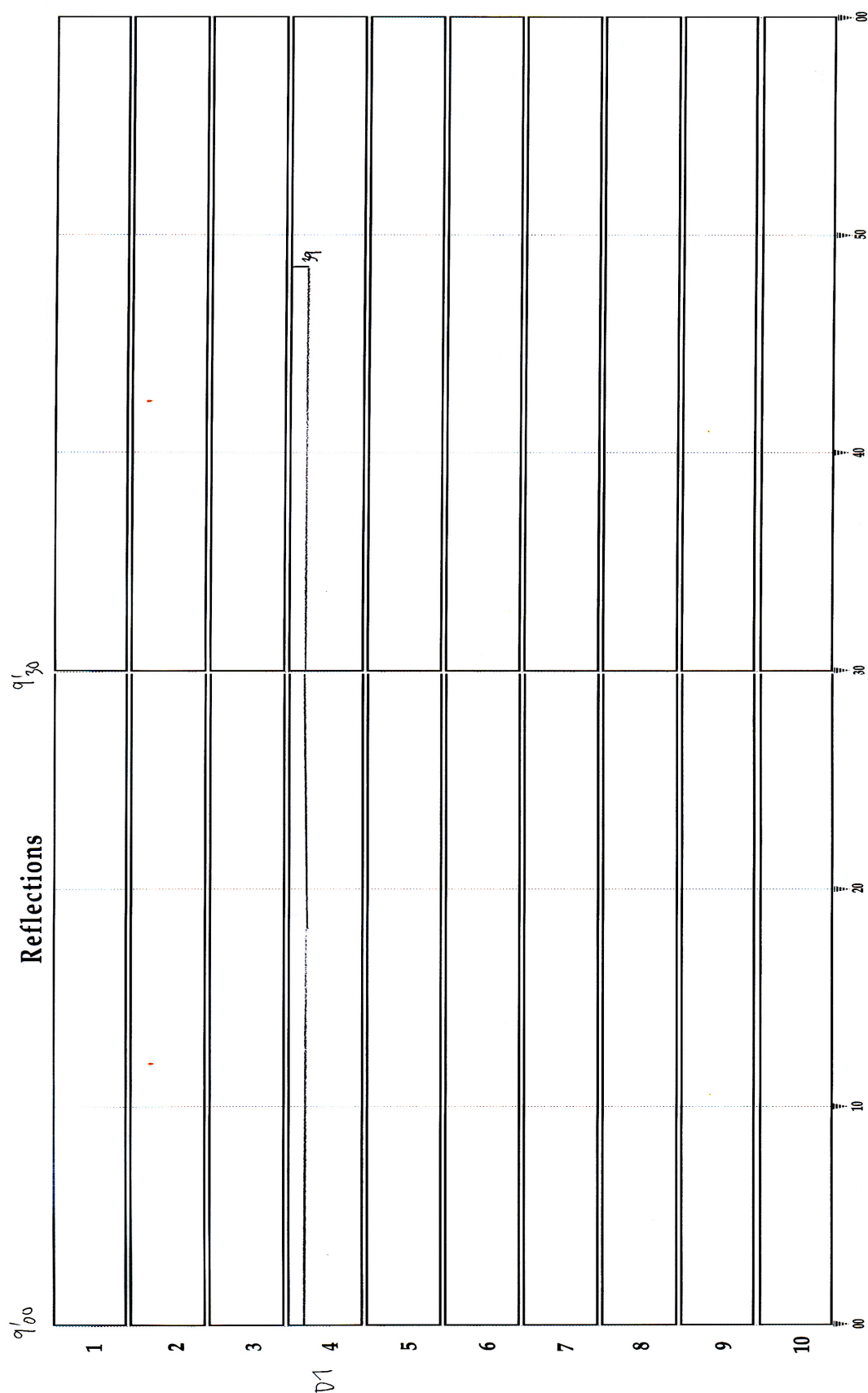
Appendix 5m: *Reflections* – Loudspeaker configuration for each sound



Appendix 5n: *Reflections* – Loudspeaker configuration for each sound



Appendix 5o: *Reflections* – Loudspeaker configuration for each sound



Appendix 6: Loudspeaker content

①

Reflections									
0	1	2	3	4	5	6	7	8	9
1	A	L	P	Ld=50					
2	B	L	I	R					
3	E2	L	D	L	S1	L30	S2	R60	S1
4									
5	N4	R	T2	L	G1	L	F2	L	
6	R	L25							
7	H	R	O	L	F2	L	E2	L	A
8	K3	L							
9									
10	J3	L	C2	L					
0	1	2	3	4	5	6	7	8	9

③ (-1,5dB)

Reflections									
0	1	2	3	4	5	6	7	8	9
1	A	L	P	L					
2	B	L	T1	L	I	L			
3	Q	R40	S1	L10	S2	L20	S1	L10	
4									
5	E1	L	G1	R	Q	R20			
6	F1	L	N1	L	K1	L	R	L75	
7	H	L	O	L	A	L			
8	J1	L	F1	L	E1	L			
9	C1	L							
10									
0	1	2	3	4	5	6	7	8	9

⑤ (-2dB)

Reflections									
0	1	2	3	4	5	6	7	8	9
1	A	R	P	R					
2	B	R	T1	R	G2	L	F	R	
3	Q	L50	S1	R30	S2	L60	S1	R30	
4									
5	E1	R	Q	L50					
6	F1	R	R	R75					
7	H	R	O	L	A	R			
8	J1	R	N2	L	K3	R	E1	R	
9									
10	C2	R							
0	1	2	3	4	5	6	7	8	9

⑦ (-2,5dB)

Reflections									
0	1	2	3	4	5	6	7	8	9
1	A	R	P	R50					
2	B	R	N3	R	G2	R	I	L	
3	E2	R	Q	R	S1	R10	S2	R	S1
4									
5	T2	R	Q	R	F2	R			
6	K1	R	R	R25					
7	H	L	O	L	F2	R	E2	R	A
8									
9	C1	R							
10									
0	1	2	3	4	5	6	7	8	9

② (-2dB)

Reflections									
0	1	2	3	4	5	6	7	8	9
1	A	L	P	L25					
2									
3	S1	L20	S2	L	S1	L20			
4									
5	N4	L	G1	L	F2	L			
6	F1	L	R	L50					
7	H	R	O	R	F2	L	A	L	
8	F1	L							
9	J2	L	C1	L					
10	C2	L							
0	1	2	3	4	5	6	7	8	9

④ (-4dB)

Reflections									
0	1	2	3	4	5	6	7	8	9
1									
2									
3	S1	L	S2	L40	S1	L			
4									
5	E1	L+R	G1	R					
6	F1	L+R	N1	R	R	L+R=100			
7	M1		H	L	O	R			
8	F1	L+R	E1	L+R					
9	C1	L							
10	C2	R							
0	1	2	3	4	5	6	7	8	9

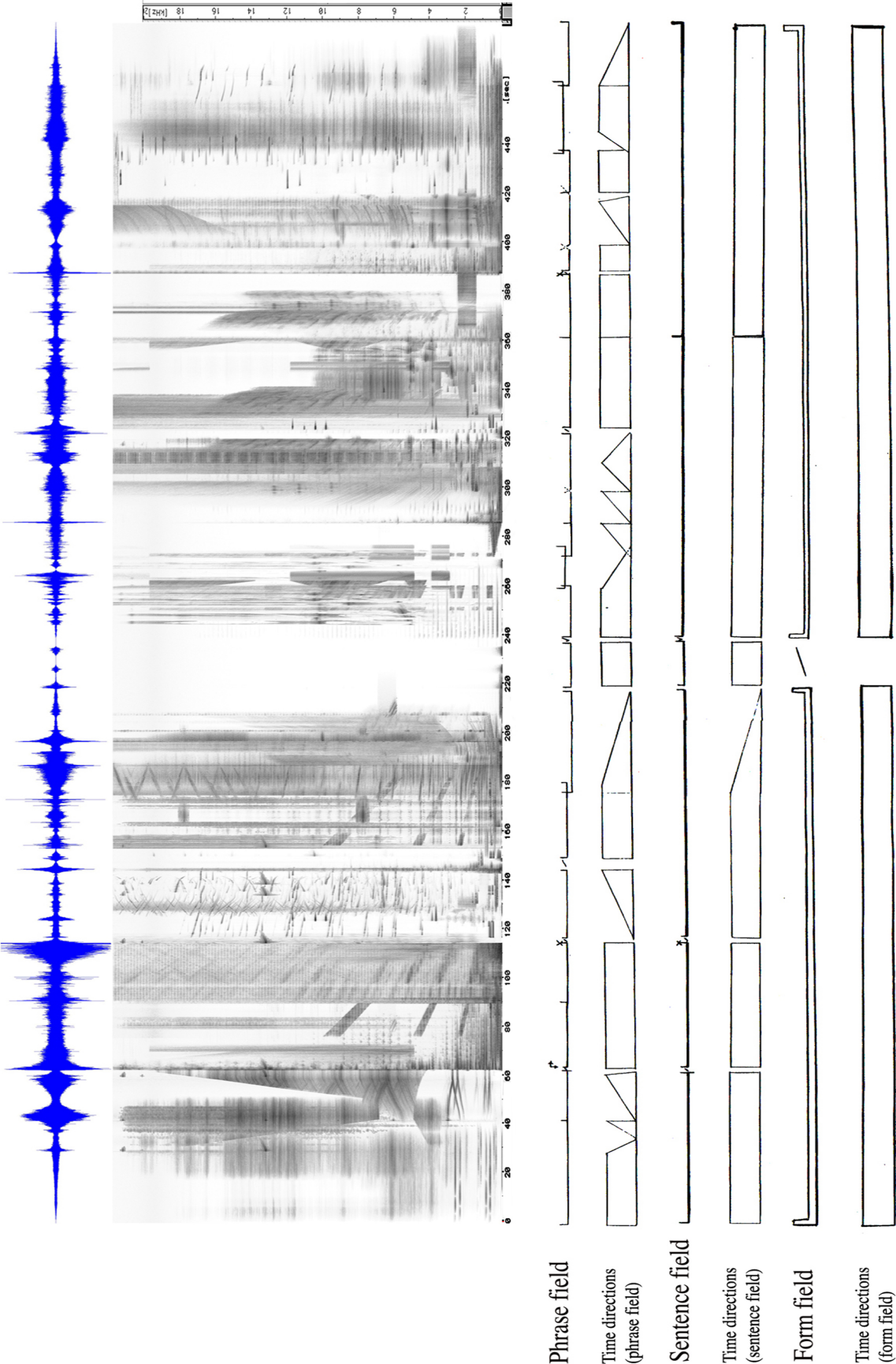
⑥ (-2dB)

Reflections									
0	1	2	3	4	5	6	7	8	9
1	A	R	P	R25					
2	G2	L							
3	S1	R20	S2	R	S1	R20			
4									
5	F2	R							
6	F1	R	R	R50					
7	H	R	O	R	F2	R	A	R	
8	N2	R	F1	R					
9	J2	R	C1	R					
10	C2	R							
0	1	2	3	4	5	6	7	8	9

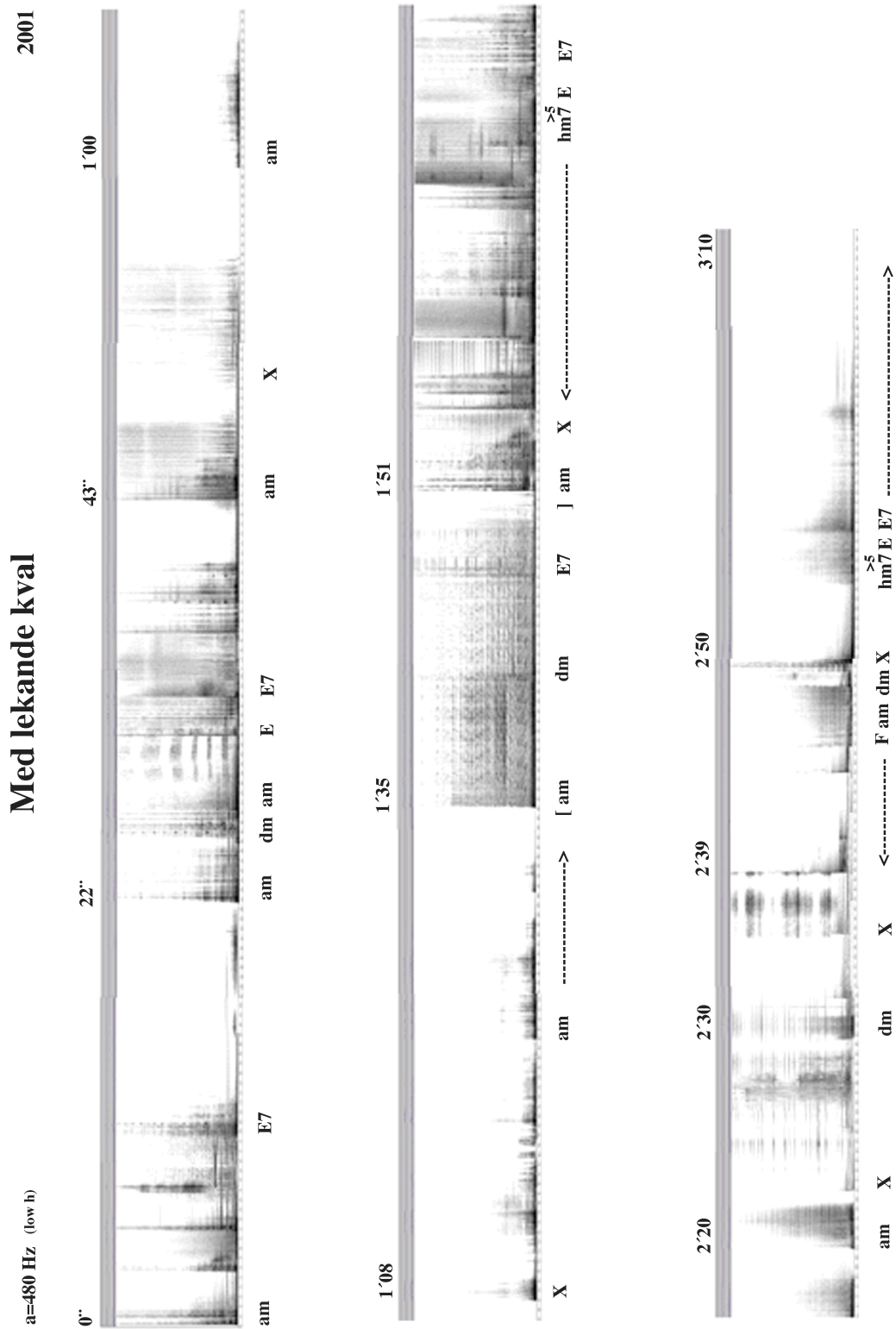
⑧ (-4dB)

Reflections									
0	1	2	3	4	5	6	7	8	9
1									
2	N3	L	G2	R					
3	M3	M	E2	L+R	S1	R	S2	R40	S1
4									
5	F2	L+R							
6	R	L+R							
7	H	L	O	R	F2	L+R	E2	L+R	
8									
9	C1	R							
10	J3	R	C2	L					
0	1	2	3	4	5	6	7	8	9

Appendix 7: *Clandestine Parts* – Sonogram score



Appendix 8: *Med lekande kval* – Sonogram score



Appendix 9a: *Within a Dream* – Songs by Carin Bartosch-Edström

Eternity

Text: William Blake
Musik: Carin Bartosch Edström 2002

Sopran

Altbloekflöjt

f

he who binds him - self with joy He who binds him - self with

f

6

Sopran

joy Does the winged life de - stroy; he who binds him - self with joy

12

Sopran

Does the winged life de - stroy; But He who binds him -

17

Sopran

self with joy Does the winged life de - stroy;

Appendix 9b: *Within a Dream* – Songs by Carin Bartosch-Edström

21 Sopran

But he he who kis - - - ses

p

pp

25 Sopran

the joy as it flies

29 Sopran

lives lives in e - ter -

33 Sopran

nu - ty lives in e - ter - ni - ty's

37 Sopran

sun - - - - rise.

-2-

Appendix 9c: *Within a Dream* – Songs by Carin Bartosch-Edström

Koral

Più lento

Carin *f*

Claudia *f*

9

15

23

kort!

kort!

kort!

kort!

Appendix 9d: *Within a Dream* – Songs by Carin Bartosch-Edström

Go not too near a House of Rose

Musik: Carin Bartosch 2002

Text: Emily Dickinson

1 ♩ 96 *p*

Carin

Claudia

p

Go not too near a

4

Carin

Claudia

house of rose, The de - pre - da - tion of a breeze

7

Carin

Claudia

Or in - un - da - tion of a dew a - larm its walls a - way

10

Carin

Claudia

a - larm its walls a -

13

Carin

Claudia

way

Appendix 9e: *Within a Dream* – Songs by Carin Bartosch-Edström

17
Carin
Nor try to tie the but-ter-fly;

21
Carin
Nor climb the bars of ec - - - sta - sy.

25
Carin
f In *p* in - se - cu - ri -

28
Carin
ty to lie Is joy's in - sur - - -

31
Carin
ing qua - li - ty.

Claudia

Appendix 9f: *Within a Dream* – Songs by Carin Bartosch-Edström

A Dream within a Dream

Musik: Carin Bartosch 2002

Text: Edgar Allan Poe

1 88 *p*

Carin

Claudia

f *>* *p*

Dream is but a dream

5

Carin

Claudia

f

9

Carin

Claudia

> *p*

Dream is but a dream with-in a dream.

13

Carin

Claudia

Take this kiss up - on the brow! And, in par ting

17

Carin

Claudia

from you now, this much let me a - vow_ You are not *sub* *p*

Appendix 9g: *Within a Dream* – Songs by Carin Bartosch-Edström

21

Carin

wrong, who deem, That my life has been a

Claudia

5 5

25

Carin

dream Dream is but a dream with-in a

Claudia

pp pp

29

Carin

dream. Yet if hope has flown a - way

Claudia

mf mf

33

Carin

In a night or in a day,

Claudia

f

37

Carin

In a vi - sion, or in none, Is it there - for the less

Claudia

p p

5 5

Appendix 9h: *Within a Dream* – Songs by Carin Bartosch-Edström

41

Carin

gone?

All

that we see

pp

p

3

45

Carin

all that we seem

is but at

pp

49

Carin

dream

with-in a dream.

pp

Appendix 10a: *Utresa* – Frequency chart

Barabiti	Frekvens	Cent	Indeks	Frekvens	Cent	Indeks	Frekvens	Cent	Indeks	Frekvens	Cent	Indeks	Frekvens	Cent	Indeks	Frekvens	Cent	Indeks	Frekvens	Cent	Indeks																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
Spectrum Transp.100	173	470,2673	1,31213873	1,1	190,3	1,31	226,63	1,38	238,74	1,43	247,39	1,52	262,96	1,67	288,91	1,83	316,59	1,97	340,81	2,1	363,3	173																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									

Appendix 10b: *Utresa* – Frequency chart

S anabit Spectrum Transp.152	Prak	Cent	Indax	Frakxons										Cent	Index	Frakxens		Cent	index/stala									
				Frakxons	Frakxons	Frakxons	Frakxons	Frakxons	Frakxons	Frakxons	Frakxons	Frakxons	Frakxons															
262,96				1,1	289,26	1,31	344,48	1,38	362,88	1,43	376,03	1,52	399,7	1,67	439,14	1,83	481,22	1,97	518,03	2,1	552,22	173	1,31213873	470,2673	164,991243	164,991243	1,1	
345,04					379,54		452	476,16		493,41		524,46		631,42		679,73		724,58		779,90556		227	227	302,4521414	302,4521414	467,443384	467,443384	1,31
525,92			2	1199,9			689,96	725,77		752,07		799,4	878,29	962,43		1036,1		1104,4		1199,90556		346	346	344,4776	344,4776	557,558038	557,558038	1,38
722				1748,4	2,7457			945,82	996,36		1032,5		1097,4	1205,7		1321,3		1516,2		1748,44896		548,533982	548,533982	616,140694	616,140694	619,169445	619,169445	1,43
788,88			3	1901,8			1033,4	1088,7		1128,1		1199,1	1317,4	1443,7		1554,1		1656,6		1901,80532		519	519	376,0328	376,0328	724,828542	724,828542	1,52
1033,6				2369,5	3,9306		1354	1426,4		1478		1571,1	1726,1	1891,5		2036,2		2170,6		2369,52876		680	680	399,6992	399,6992	887,747854	887,747854	1,67
1322,4				2796,1	5,0289		1732,3	1824,9		1891		2010	2208,4	2420		2605,1		2777		2796,07197		870	870	439,1432	439,1432	1046,13004	1046,13004	1,83
2020,1				3529,5	7,6821		2646,3	2787,7		2888,7		3070,5	3373,5	3696,7		3979,6		4242,2		3529,51881		733,446831	733,446831	481,2168	481,2168	1173,74238	1173,74238	1,97
2395,5				3822,4	9,9883		3134,1	3301,6		3421,2		3636,6	3995,4	4378,2		4713,2		5024,2		3822,40908		292,902719	292,902719	518,0312	518,0312	1284,36611	1284,36611	2,1
2901,7				4156,4	11,035		3801,2	4004,3		4149,4		4410,6	4845,8	5310,1		5716,3		6093,5		4156,44066		334,031947	334,031947	552,216	552,216			
3219,4				4336,3	12,243		4217,4	4442,7		4603,7		4893,4	5376,3	5891,4		6342,1		6760,7				179,848491	179,848491					
3997,6				4711,1	15,202		5236,9	5516,7		5716,6		6076,4	6676	7315,6		7875,3		8395		4711,09185		374,807538	374,807538					
4336,1				4852,6	16,497		5682,9	5986,6		6203,5		6593,9	7244,6	7938,7		8546		9110		4852,58775		141,495961	141,495961	16,4971098	16,4971098			
4774,3				5018,5	18,156		6254,4	6588,6		6827,3		7257	7973,1	8737		9403,4		10026		5018,46103		165,8732749	165,8732749					

Appendix 10c: *Utresa* – Frequency chart

[illegible]

Appendix 11a: *Joker* – Frequency chart for the theme of Hearts

C1 Spektrum Transp.1.00	Frekvens	Cent	Frekvens	Cent	index	Frekvens	Cent	index/skala
32	1213,38	32	1213,38	2,01563	32	130,2191	130,219	1,078125
64,5	2413,28	64,5	2413,28	2	34,5	73,674855	203,894	1,125
129	3612,52	129	3612,52	8,05938	36	250,28425	454,178	1,3
257,9	4812,42	257,9	4812,42	16,1188	41,6	202,0435	656,222	1,460938
515,8	5705,22	515,8	5705,22	26,9969	46,75			
863,9	6363,63	863,9	6363,63	39,4906				
1263,7	6892,25	1263,7	6892,25	53,5938				
1715	7463,5	1715	7463,5	74,5469				
2385,5	7906,85	2385,5	7906,85	96,3063				
3081,8	8639,88	3081,8	8639,88	147,081				
4706,6	9017,6	4706,6	9017,6	182,944				
5854,2	9259,2	5854,2	9259,2	210,344				
6731		6731						

Appendix 11b: *Joker* – Frequency chart for the theme of Hearts

C2	Frekvens	Cent	Frekvens	Cent	index	Frekvens	Cent	index/skala
Spektrum								
Transp.1.00	36	1199,91	36	1199,91	2	32	130,219	1,078125
	72	2391,38	72	1191,47	2	34,5	203,894	1,125
	143,3	3591,89	143,3	1200,51	7,96389	36	454,178	1,3
	286,7	4791,79	286,7	1199,91	15,9278	41,6	656,222	1,460938
	573,4	5493,69	573,4	701,9	23,8917	202,0435		
	860,1	5644,33	860,1	150,642	26,0639	46,75		
	938,3	6330,11	938,3	685,774	38,7333			
	1394,4	6867,51	1394,4	537,405	52,8333			
	1902	7351,12	1902	483,611	69,8611			
	2515	7778,3	2515	427,178	89,4139			
	3218,9	8154,74	3218,9	376,435	111,133			
	4000,8	8477,85	4000,8	323,115	133,939			
	4821,8		4821,8					

Appendix 11c: *Joker* – Frequency chart for the theme of Hearts

C3 Spektrum Transp.1.00	Frekvens	Cent	Frekvens	Cent	index	Frekvens	Cent	index/skala
34,5	34,5	1199,91	34,5	1199,91	2	32	130,219	1,078125
69	69	2399,81	69	1199,91	2	34,5	203,894	1,125
138	138	3595,32	138	1195,51	7,97971	36	454,178	1,3
275,3	275,3	4630,42	275,3	1035,1	14,5101	41,6	656,222	1,460938
500,6	500,6	5497,13	500,6	866,702	23,9391	46,75		
825,9	825,9	6199,1	825,9	701,97	35,9101			
1238,9	1238,9	6798,98	1238,9	599,884	50,7826			
1752	1752	7281,43	1752	482,448	67,1043			
2315,1	2315,1	7732,02	2315,1	450,591	87,0551			
3003,4	3003,4	8141,23	3003,4	409,209	110,27			
3804,3	3804,3	8486,04	3804,3	344,81	134,574			
4642,8	4642,8	9073,82	4642,8	587,779	188,983			
6519,9	6519,9		6519,9					

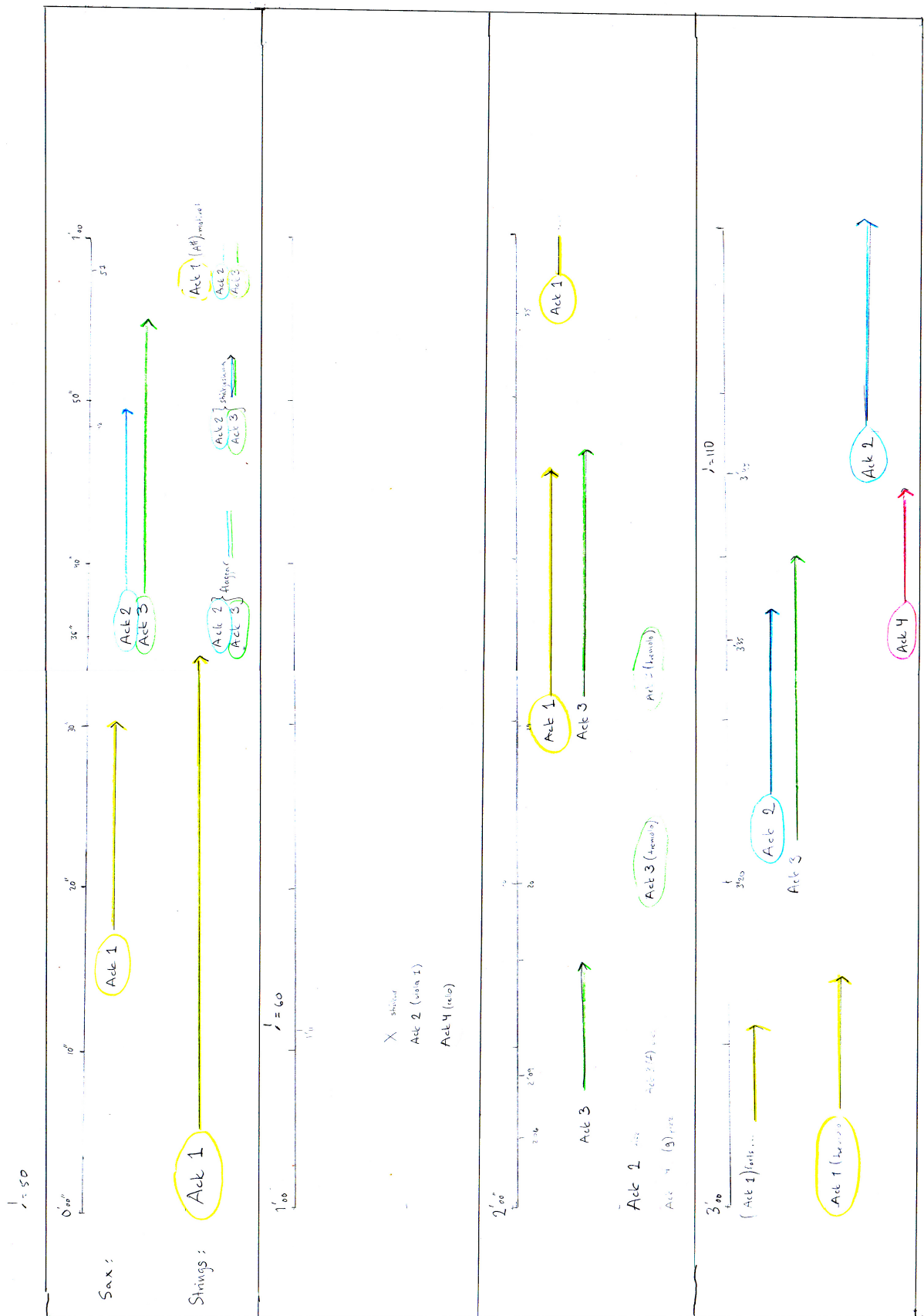
Appendix 11d: *Joker* – Frequency chart for the theme of Hearts

C4 Spektrum Transp.1.00	Frekvens	Cent	Frekvens	Cent	index	Frekvens	Cent	index/skala
	46,75	1199,91	46,75	1199,91	2	32	130,219	1,078125
	93,5	2399,81	93,5	1199,91	2	34,5	203,894	1,125
	187	3040,79	187	640,977	5,79251	36	454,178	1,3
	270,8	4799,39	270,8	1758,6	15,9979	41,6	656,222	1,460938
	747,9	5048,99	747,9	249,603	18,4791	202,0435		
	863,9	5559,93	863,9	510,932	24,8235	46,75		
	1160,5	5689,64	1160,5	129,715	26,7551			
	1250,8	6183,14	1250,8	493,502	35,5807			
	1663,4	6711,12	1663,4	527,977	48,2695			
	2256,6	7161,47	2256,6	450,35	62,6118			
	2927,1	7567,48	2927,1	406,006	79,1615			
	3700,8	7915,97	3700,8	348,49	96,815			
	4526,1		4526,1					

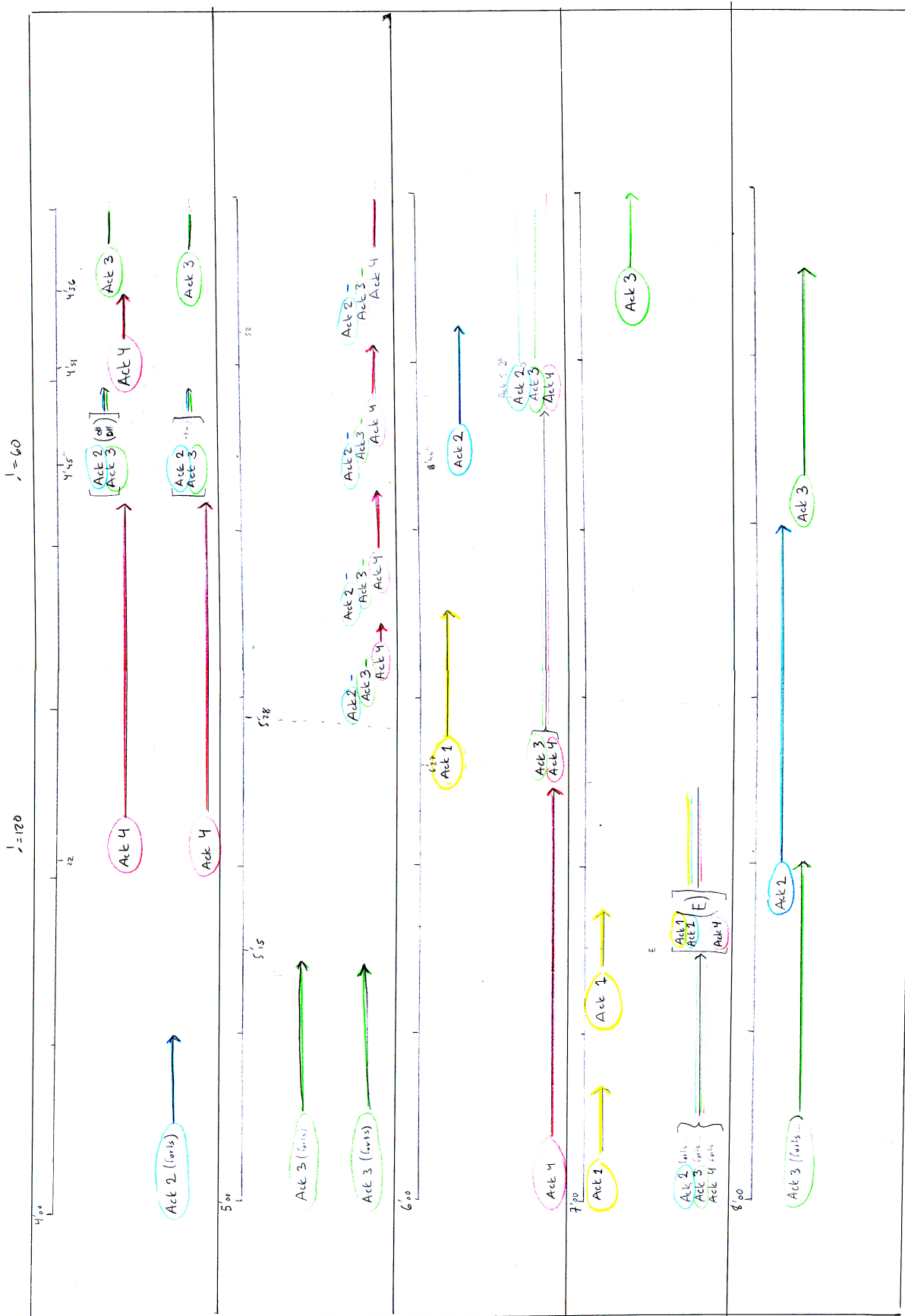
Appendix 11e: *Joker* – Frequency chart for the theme of Hearts

C6 Spektrum	Frekvens	Cent	index				index/skala
			Frekvens	Cent	Frekvens	Cent	
41,6	41,6	1195,74	32	1195,74	130,2191	130,219	1,078125
83	83	2395,64	34,5	1,99519	203,894	203,894	1,125
166	166	3173,71	36	2	454,178	454,178	1,3
260,2	260,2	4470,95	41,6	6,25481	656,222	656,222	1,460938
550,5	550,5	5162,23	46,75	13,2332			
820,7	820,7	5999,53		19,7284			
1331,2	1331,2	6570,83		32			
1851,7	1851,7	7064,11		44,512			
2462,2	2462,2	7413,41		59,1875			
3012,7	3012,7	7732,88		72,4207			
3623,3	3623,3	8228,5		87,0986			
4824,4	4824,4	8829,33		115,971			
6826,2	6826,2			164,091			

Appendix 12a: Ytspänning – Overall time-grid



Appendix 12b: Ytspänning – Overall time-grid



Appendix 13a: Sound example Contents

(Appendix 13c=CD with Sound examples)

Sound example 1: *Clandestine Parts* – Martial art time-grid (slightly filtered).

Sound example 2: *Clandestine Parts* – Clock sound illustrating Figure 2.23.

Sound example 3: *Clandestine Parts* – Sound example 1+2 mixed together.

Sound example 4: *Med lekande kval* – Sound illustrating Figure 2.39 (Red circle marked 1=a sound filtered slightly to contain the pitch “E”).

Sound example 5: *Med lekande kval* – Sound illustrating Figure 2.39 (Blue circle marked 2=tonal centre of pitches A+G#).

Sound example 6: *Med lekande kval* – Different sound illustrating Figure 2.39 (Blue circle marked 2=tonal centre A+G#).

Sound example 7: *Med lekande kval* – Sound illustrating Figure 2.39 (Green circle marked 3=A-minor chord).

Sound example 8: *Med lekande kval* – Different sound illustrating Figure 2.39 (Green circle marked 3=A-minor chord).

Sound example 9: *Med lekande kval* – Sound illustrating Figure 2.39 (Yellow circle marked 4=E7 chord).

Sound example 10: *Med lekande kval* – Sound illustrating Figure 2.39 (Yellow and purple circle marked 5=E7 chord+C).

Sound example 11: *Med lekande kval* – Sound illustrating Figure 2.39 (The whole note example=Sound example 4-10 mixed together).

Sound example 12: *Utresa* – The wooden drum sound used to structure harmony in *Utresa*.

Sound example 13: *Utresa* – A additive synthesis illustration of the scale based on the dissonance curve.

Sound example 14: *Utresa* – Sound illustrating Figure 2.51 (The tonal centres throughout the piece).

Sound example 15: *Joker* – The original sound used for Clubs.

Sound example 16: *Joker* – The processed sound used to illustrate the theme of Clubs.

Sound example 17: *Joker* – Scale step 1 mapped onto the cement mixer sound for Hearts.

Sound example 18: *Joker* – Scale step 2 mapped onto the cement mixer sound for Hearts.

Appendix 13b: Sound example Contents continued...

Sound example 19: *Joker* – Scale step 3 mapped onto the cement mixer sound for Hearts.

Sound example 20: *Joker* – Scale step 4 mapped onto the cement mixer sound for Hearts.

Sound example 21: *Joker* – Scale step 5 mapped onto the cement mixer sound for Hearts.

Sound example 22: *Joker* – A transition from Diamond spectrum to a Spade spectrum.

Sound example 23: *Joker* – A Diamond spectrum transposition (1.49) mapped onto the rhythmic theme of Hearts.

Sound example 24: *Joker* – Additive synthesis example of Hearts spectrum, Scale step 1.

Sound example 25: *Joker* – Additive synthesis example of Hearts spectrum, Scale step 2.

Sound example 26: *Joker* – Additive synthesis example of Hearts spectrum, Scale step 4.

Sound example 27: *Joker* – Additive synthesis example of Hearts spectrum, Scale step 5.

Sound example 28: *Joker* – Additive synthesis example of Clubs spectrum, Scale step 1.

Sound example 29: *Joker* – Additive synthesis example of Diamond spectrum, Scale step 1.

Sound example 30: *Joker* – Additive synthesis example of Spade spectrum, 22.5 Hz.

Sound example 31: *The Ringing Stone of Håga* – The original ringing stone sound used to structure harmony in the piece.

Sound example 32: *The Ringing Stone of Håga* – Sound illustrating Figure 2.81 (The ProTools example) and Figure 2.82.

Sound example 33: *The Ringing Stone of Håga* – The theme at 2'05 in the piece.

Sound example 34: *Taal Bundu* – A version of the original melody created of recordings of extended playing techniques.

Appendix 14a: CD contents for selected Works in stereo

(Appendix 14c=CD)

<u>Track</u>	<u>Title</u>	<u>Duration</u>	<u>Year</u>
1.	Ti Chor - saxophone quartet (s, a, t, bar) and fixed media in stereo Recorded at Fylkingen, Stockholm, September 2010	8'50	1997/1999
2.	Mayfly - fixed media in stereo	2'20	1999
3.	Within a Dream - fixed media in stereo	7'50	2002
4.	Taal Bundu - saxophone quartet (s, a, t, bar) and fixed media in stereo Recorded at Fylkingen, Stockholm, September 2010	9'15	2009
5.	Ytspänning - string orchestra (9 vn, 3 va, 2 vc, 1 cb) and saxophone quartet (s, a, t, bar) Samples of saxophone quartet with MIDI-string simulation	10'00	2010
6.	Echo in Silence - percussion, trombone and fixed media in stereo Recorded at Fylkingen, Stockholm, September 2010	8'00	2010

Approximate duration:

46 minutes

Appendix 14b: CD contents for stereo versions of the multi-channel Works

(Appendix 14d=CD)

<u>Track</u>	<u>Title</u>	<u>Duration</u>	<u>Year</u>
1.	Reflections - fixed media in stereo, 8 and 12-channels Collaboration work with composer Jens Hedman	9'00	1995/1999
2.	Clandestine Parts - fixed media in stereo and 8-channels	8'09	2000
3.	Med lekande kval - fixed media in stereo and 5-channels	3'10	2001
4.	Utresa - fixed media in stereo and 5-channels	7'00	2003
5.	Joker - fixed media in stereo and 5-channels	13'00	2003
6.	Klangstenen i Håga - fixed media in stereo and 5-channels	7'40	2006

Approximate duration:

48 minutes